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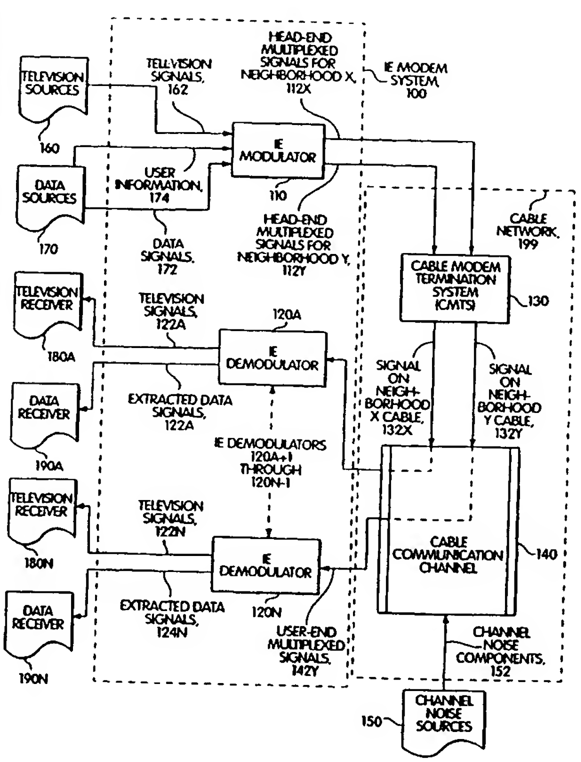
(54) Title: SYSTEM AND METHOD FOR VARIABLE-RATE MODULATION AND DEMODULATION OF DATA USING INFORMATION EMBEDDING IN TELEVISION SIGNALS



(57) Abstract: A system is described for providing data signals to user ends of a cable network using variable-rate information-embedding. The system includes a data rate selector that selects, for example, a first host signal from two or more television signals based on an association between the first host signal and a first user end. A first data signal is embedded into the first host signal at a first data rate, thereby generating a first composite signal that comprises a digitally watermarked version of the first host signal. The first data signal may be associated with the firs user end. The first data rate is selected by a data rate selector that may, but need not, be included in a modulator coupled to the head end of the cable network. Alternatively, or in addition, data rate selectors may be included in demodulators at the users ends. The data rate selectors may select a rate for embedding data to the be transmitted to a particular user end based on the signal-to-noise ratio over the cable network to that user end. Determination of this ratio may be based, at least in part, on the distance from the head end of the cable network to that user end. Also, the data rate may be based on a user-defined acceptable level of distortion. The system may selected host signals based on signal-to-noise ratios over the cable network to the respective user ends.

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SYSTEM AND METHOD FOR VARIABLE-RATE MODULATION AND DEMODULATION OF DATA USING INFORMATION EMBEDDING IN TELEVISION SIGNALS

RELATED APPLICATIONS

The following applications are related to the present application: U.S. Patent Application entitled "SYSTEM AND METHOD FOR BACKWARD-COMPATIBLE MODULATION AND DEMODULATION OF DATA USING INFORMATION EMBEDDING IN TELEVISION SIGNALS," attorney docket number C1078/7000, naming Brian Chen and Gregory W. Wornell as the inventors, assigned to the assignee of the present invention, and filed concurrently herewith; and SYSTEM AND METHOD FOR VIRTUAL NODE DISTRIBUTION OF DATA EMBEDDED IN TELEVISION SIGNALS," attorney docket number C1078/7001, naming Brian Chen and Gregory W. Wornell as the inventors, assigned to the assignee of the present invention, and filed concurrently herewith.

FIELD OF THE INVENTION

The present invention relates generally to the transmission of data in television signals and, more particularly, to the embedding of data in television signals using digital watermarking techniques.

BACKGROUND

A variety of commercial applications exist for providing data to a user through communication channels used for transmitting television signals. For example, closed captioning and teletext systems are employed to display textual data that are associated with a television program. Additional applications include sending telephony, Internet, video-enhancement, video-on-demand, video-streaming, or audio-streaming data over television communications channels. These channels include those associated with broadcast "over-the-air" from ground-based antennas, from satellites, and over cable networks.

Cable networks typically are referred to as having a "head end" from which the cable television signals are transmitted. The communication channels through which the transmissions occur typically include fiber optic cables and coaxial wire cables, as well as a variety of switches, relays, and other conventional network components. Public switched or other telephone networks may also constitute, or be included in, the cable

network. For sake of convenience, these communication channels are sometimes referred to herein simply as "cables." The television signals are received at what are referred to herein as "user ends." For example, a cable-network customer receives the television signals at a user end where the signals may be coupled to television receivers, video cassette recorders, computers, and/or other devices.

A variety of sources of television signals (hereafter, "television sources") are coupled to the head end so that the television signals may be transmitted over the cable network. These television sources may include, for example, various commercial or public broadcast systems or organizations. Television signals typically include both video signals and associated audio signals, and also may include data signals. The television signals typically are multiplexed at the head end into what is referred to herein as "head-end multiplexed signals," meaning a group of television signals assembled at various carrier frequencies across a band of frequencies. The organizational scheme according to which these signals are assembled at the head end is commonly referred to as a "cable plant."

The organization of a typical conventional cable plant, referred to as conventional cable plant 169, is graphically represented in Figure 1B. Frequency axis 160 of Figure 1B is not shown to scale. As indicated on axis 160, the portion of cable plant 169 between zero and 50 Megahertz (MHz) is referred to as the "return channel" and is reserved for carrying data from the user ends back to the head end. Current systems use either the range of 5 to 39 MHz or 5 to 42 MHz. Examples of the data transmitted over the return channel include user selections of video-on-demand services or requests for other download services. The portion of cable plant 169 between 50 MHz and 550 MHz is used to transmit conventional analog television signals in television channels having a bandwidth of 6 MHz each. Examples of these channels are labeled 168A-C, generally and collectively referred to hereafter as analog television channels 168. For instance, an analog television signal provided by one television network or station may occupy channel 168A, an analog television signal provided by another television network or station may occupy channel 168C, and so on.

The portion of cable plant 169 between 550 MHz and 750 MHz is used to transmit conventional digital television signals. The television channels in this range also have a bandwidth of 6 MHz, into which one high definition television (HDTV) signal may be placed. However, multiple standard definition television signals (SDTV)

may be combined in each of these channels in the 550 MHz to 750 MHz range. Both HDTV and SDTV employ digital signals. An example of a digital television channel is labeled 164A, and digital television channels may hereafter be generally and collectively referred to as digital television channels 164.

In addition to carrying digital television signals, a portion of cable plant 169 between 550 and 750 MHz may be dedicated to carrying conventional data signals from the head end to the user ends. In particular, an industry standard referred to as the Data Over Cable Service Interface Specification (DOCSIS) provides that cable operators may select portions of the cable plant within this range for the transmission of data signals. As noted, these data signals may include captioning, teletext, telephony, Internet, television-enhancement, video-on-demand, video-streaming, audio-streaming, or other types of data.

Typically, user-end multiplexed signals are provided to users in accordance with what is referred to as a "multi-drop" system. Figure 9A shows a conventional multi-drop system in which a common cable provides the same user-end multiplexed signals 910X to all of the users in what is referred to for convenience herein as a "neighborhood." In Figure 9A, a portion of the users in an illustrative neighborhood X are represented by homes 901A-E (hereafter, "homes 901"). The word "homes" is used herein for convenience, but it will be understood that homes 901 need not be residences. Rather, any of them could be a business, school, or any other facility, place, or user that constitutes a user end of the cable network. Homes 901 typically are in the same geographic area. Homes located in another neighborhood, for example, "neighborhood Y," typically receive user-end multiplexed signals from another cable that is common to all of the homes in that other neighborhood. The number of homes in a typical cable neighborhood may be 500 to 2,000.

Because the same cable serves all of homes 901 in the illustrated example of Figure 9A, each of homes 901 may access the same television and data signals as provided by multiplexed signals 910X (assuming that each home has the necessary equipment to unscramble or otherwise enable each of the signals). In accordance with the DOCSIS standard referred to above, data may be provided in the portion of conventional cable plant 169 represented by conventional data channel 166 of Figure 1B. The data provided to homes 901 in multiplexed signals 910X may thus be referred to for convenience as conventional data signals 166X.

The bandwidth of conventional data signals 166X is limited; thus the rate at which data may be transmitted to homes 901 in this portion of multiplexed signals 901X is also limited. In accordance with the bandwidth specified in the DOCSIS standard, this maximum data rate is about 27 million bits per second (Mbps). A variety of conventional techniques are employed to distribute these 27 Mbps among homes 901. For example, addressable data packets may be used so that home 901A is allowed exclusive access to data packets addressed to it, home 901B is allowed exclusive access to data packets addressed to it, and so on.

Some applications, such as use of the Internet, typically involve relatively high rates of data transmission to users. For example, so-called "broadband" access to data downloads from the Internet, such as is generally desirable for streaming video and other uses, currently involves data transfer rates on the order of 1 Mbps. Assuming this rate as a typical one for illustrative purposes, the entire capacity of conventional data signals 166X is required to service 27 homes in neighborhood X that concurrently seek to download Internet data at a rate of 1 Mbps. If additional users in neighborhood X concurrently seek to access data, then either they must be denied access, current data users must be eliminated, and/or a rationing scheme must be imposed.

Cable companies typically ration the 27 Mbps so that all subscribers in a neighborhood may be served during periods of high demand. For example, if 54 homes in neighborhood X concurrently seek broadband Internet access (and assuming in this example no other concurrent data uses in the neighborhood), each home may be limited to a rate of 0.5 Mbps. Thus, rationing schemes result in degradation of data service (in the form of slower data rates) to some or all users. Degradation of data service may not be unusual during peak demand periods since, as noted, 500 or more homes may share the same 27 Mbps of data capacity. Degradation of Internet service often is of particular concern to the cable company because high-speed Internet access is advertised as an advantage of subscribing.

Several approaches are available for addressing this problem of limited data capacity in the conventional multi-drop cable configuration. One approach, graphically illustrated in Figure 9B, is simply to reduce the number of homes in a cable neighborhood. Alternatively stated, additional cable neighborhoods may be created, each associated with its own common cable. Thus, in Figure 9B, homes 901A, B, and C are served by multiplexed signals 910X' so that an illustrative three homes share the 27

Mbps data capacity of conventional data signals 166X' rather than the illustrative five homes that shared this capacity in the configuration of Figure 9A. The other two cable users, homes 901D and 901E, now share a separate cable that provides conventional data signals 166Y in multiplexed signals 910Y. Homes 901D and 901E thus share an additional 27 Mbps of data capacity provided by conventional data signals 166Y. A disadvantage of this approach, however, is the significant additional expense to the cable company of providing the additional cable from the head end to the users in neighborhood Y.

Other approaches to increasing data capacity are applicable not only to cable systems, but also to other forms of television broadcasting such as over-the-air or satellite broadcasting. A reason to apply these approaches in non-cable systems is to increase opportunities to provide a variety of data services.

One of these approaches is to replace one or more television signals with data signals. For example, a cable operator could replace the television signals transmitted over one or more of analog television channels 168, and/or over digital television channels 164, with data only. A disadvantage of this approach is that the elimination of television signals typically reduces revenues and also reduces the attractiveness of the cable service to users because of the reduced choice of television signals.

A third conventional approach to increasing the data capacity of cable networks, or of other television broadcasting systems, is to transmit the data with one or more analog television signals according to certain approved conventional methods. In the United States, the Federal Communications Commission (FCC) has approved the inclusion of data signals with analog television signals according to certain methods in over-the-air television broadcast transmissions. *See* "Digital Data Transmission Within the Video Portion of Television Broadcast Station Transmissions," FCC Report and Order, MM docket No. 95-42 (approved June 21, 1996; published June 28, 1996). Even prior to that order, the FCC had permitted the transmission of "ancillary telecommunications services" within the Vertical Blanking Interval (VBI) of television broadcast signals in the NTSC (National Television System Committee) standard used in the United States and elsewhere. The VBI is a portion of the NTSC broadcast television signal that has no viewable content, *i.e.*, it contains no video signal. The reason for creating this blank portion is to allow time for the electron gun of the television

receiver's cathode ray tube to move from the bottom to the top of the screen after scanning an image across the screen.

The VBI has been used to transmit such data as closed captioning and HTML-formatted information. For example, using the Intercast protocol developed by Intel Corporation in 1996, CNN broadcasts links to its Internet pages to provide additional information related to its television programs. A system for transmitting data from a user back to the head end of a cable system, using the VBI, is described in U.S. Patent No. 5,986,691 to Henderson. The Henderson patent also describes a similar technique of using a "black region," which is a portion of the video signal that is blanked out to allow the cathode ray tube's electron beam to retrace from the end of one horizontal line to the start of the next one. Other conventional techniques exploit under-utilized portions of television signals and insert data into these portions. For example, Takahiko Fukinuki and Yasuhiro Hirano, "Extended Definition TV Fully Compatible with Existing Standards," IEEE Transaction on Communications (Vol. Com-32, No. 8; August 1984), describes opportunities for inserting data used to increase video signal resolution into "vacant frequency bands . . . in those areas in the first and third quadrants that conjugate with the modulated color components in the second and fourth quadrants when the signal is analyzed in the temporal-vertical frequency domain."

The FCC order of June 1996 referred to above permits broadcasters to transmit ancillary information using so-called "overscan" methods proposed by Yes! Entertainment Corporation and A.C. Nielsen Company, as well as "sub-video" methods proposed by Digideck, Inc. and WavePhore, Inc. In the overscan method, data replaces a portion of the video signal that is not normally seen by television viewers. For example, the method proposed by Yes! Entertainment uses the extreme left edge of the picture, and other methods use the first line of active video (after the VBI) at the top of the picture. In many television receivers, these edges are blocked from viewing by the television cabinet. Overscan systems are capable of transmitting data at relatively low rates, on the order of 15 to 20 kilobits per second.

The sub-video technique takes advantage of portions of the 6-MHz bandwidth of a television signal that are typically filtered out by a television receiver. In other words, these are "blank" frequencies. Because the blank frequencies typically are not used to transmit either the video or audio portion of the television signal, data may be inserted into them without interfering with either the picture or sound presented to the viewer.

These techniques allow data rates on the order of 300 to 500 kilobits per second. The restricted data rates are due to the fact that the blank frequencies constitute a small portion of the full 6-MHz bandwidth.

Other conventional techniques are described in Walter S. Ciciora, "4.5 Mbps Data Compatibly Transmitted in 6 MHz Analog Television," paper presented at "1998 NCTA Convention in Atlanta" (hereafter referred to as the "Ciciora article"), and "EnCamera Sciences Corporation Executive Summary," 1998, both available from EnCamera Sciences Corporation of Scottsdale, Arizona. For example, a method is described involving a data signal that is double sideband amplitude modulated onto a suppressed carrier that is in quadrature phase with the video carrier. Pre-shaping of the data signal is required in accordance with this technique. Also, the data signal is limited to a certain region around the video carrier. In addition, abatement signals may be required to ameliorate distortion to the video signal that would otherwise occur in certain television receivers. This technique is said to permit data transmissions of 3.0 Mbps. Additional data capacity of 1.5 Mbps may be achieved, according to the authors of these articles, by amplitude modulation of the aural carrier of the NTSC television format. Amplitude modulation generally results, however, in a signal that occupies as much bandwidth as the sum of the bandwidths of the modulating signal and the aural signal. Yet another conventional technique, as described in the Henderson patent referred to above, is to transmit data by modulating the vestigial sideband of one or more cable television signals. This technique may be employed with quadrature amplitude modulation, phase shift key modulation, frequency shift key modulation, or another type of modulation.

SUMMARY OF THE INVENTION

In some aspects of the present invention, a system is described for variable rate embedding of data into television signals. Composite signals resulting from the information embedding process may be distributed to virtual nodes of a cable network. Data intended for users at a common virtual node are embedded into one or more common host television signals. The host signals may be analog or digital video television signals, analog or digital audio television signals, or data signals. The system selects host signals for a virtual node based on associations between those signals and the users who are intended to receive the data. Using digital watermarking techniques, the

system embeds the data into the selected host signals at the head end of the cable network, thereby generating a set of composite signals that include watermarked versions of the host signals. The rate at which data is embedded is determined in accordance with techniques described below. The composite signals are transmitted over the cable network and, at the receiving ends, are accessed by information-extracting demodulators that, among other things, extract the data from the selected composite signal. The extracted data corresponds to the data that had been embedded into the selected host signal at the head end of the cable network so that it may be provided to the user.

More specifically, in one aspect of the invention a variable-rate information-embedding modem system is described for providing a plurality of data signals to a plurality of user ends of a cable network. The system includes an information-embedding modulator that has a host signals selector that selects a first host signal from a plurality of television signals based, at least in part, on an association between the first host signal and a first user end. The modulator also has an information embedder that embeds a first data signal into the first host signal at a first data rate, thereby generating a first composite signal that comprises a watermarked version of the first host signal. The first data rate is selected by a data rate selector that may, but need not, be included in the information-embedding modulator. For example, in an implementation in which a data rate selector is not included in the information-embedding modulator, a first data rate selector may be included in a first information-embedding demodulator at a first of a plurality of user ends. The first data rate selector selects data rates for embedding information intended to be transmitted to the first user end. Similarly, a second data rate selector may be included in a second information-embedding demodulator at a second user end to select data rates for embedding information intended to be transmitted to the second user ends, and so on for any number of user ends and corresponding information-embedding demodulators. In addition, some functions of the data rate selector, described below, may be performed by a data rate selector included in the information-embedding modulator, and other functions performed by data rate selectors included in the information-embedding demodulators.

The data rate selector may select the first data rate based, at least in part, on a first signal-to-noise ratio over the cable network to the first user end. Determination of this ratio may be based, at least in part, on the distance from the head end of the cable network to the first user end. The first distance may be a default value, it may be

measured, or it may be otherwise determined. In some implementations, the data rate selector selects the first data rate based, at least in part, on a user-defined acceptable level of distortion. Also, in some implementations, the host signals selector selects the first host signal based, at least in part, on a first signal-to-noise ratio over the cable network to the first user end.

In some aspects, the host signals selector also selects a second host signal based, at least in part, on the first signal-to-noise ratio and on a second signal-to-noise ratio over the cable network to a second user end. In these aspects, the data rate selector selects a second data rate at which to embed a second data signal into the second host signal. The information embedder embeds the second data signal into the second host signal at the second data rate, thereby generating a second composite signal that comprises a watermarked version of the second host signal.

The host signals selector may determine the association between the first host signal and the first user end based, at least in part, on one or more characteristics of the first host signal. These characteristics may include, for example, the video frequency composition, or the audio frequency composition, of the first host signal. Also, in some implementations, the data rate selector may select the first data rate based, at least in part, on these or other characteristics of the first host signal.

The system may a first information-embedding demodulator coupled to the first user end for receiving a set of user-end multiplexed signals including the first composite signal. The demodulator has a first composite signals selector and splitter that selects from the set of user-end multiplexed signals a first received composite signal corresponding to the first host signal. The demodulator also has a first information extractor that extracts from the first received composite signal a first extracted data signal corresponding to the first data signal. Also included in the demodulator is a first data rate analyzer that determines a first error rate of the first extracted data signal. This determination may be based, at least in part, on a test signal included in the first data signal, on an error detection technique, or in accordance with any of a variety of other known techniques. The data rate selector may select the first data rate based, at least in part, on the first error rate. In some implementations, the first data rate analyzer also determines a second error rate of the first extracted data signal at a time subsequent to determining the first error rate. The data rate selector selects the first data rate based, at

least in part, on applying one or more statistical measures to the first and second error rates, such as by averaging them.

In some aspects of the invention, a method is described for providing a plurality of data signals to a plurality of user ends of a cable network using variable-rate information-embedding. The method includes the steps of: (1) selecting a first host signal from a plurality of television signals based, at least in part, on an association between the first host signal and a first user end; (2) selecting a first data rate; and (3) embedding a first data signal into the first host signal at the first data rate, thereby generating a first composite signal that comprises a watermarked version of the first host signal. In some implementations, the method also includes: (4) determining a first signal-to-noise ratio over the cable network to the first user end. In those implementations, step (2) may be based, at least in part, on the first signal-to-noise ratio. Step (1) may also be based, at least in part, on the first signal-to-noise ratio. Also, step (2) may be based, at least in part, on a user-defined acceptable level of distortion.

Some implementations of the method include the additional steps of: (5) determining a second signal-to-noise ratio over the cable network to a second user end; (6) selecting a second host signal from the plurality of television signals based, at least in part, on the first signal-to-noise ratio and on the second signal-to-noise ratio; (7) selecting a second data rate at which to embed a second data signal into the second host signal; and (8) embedding the second data signal into the second host signal at the second data rate, thereby generating a second composite signal that comprises a watermarked version of the second host signal.

Further aspects of the method include the step of determining the association between the first host signal and the first user end based, at least in part, on one or more characteristics of the first host signal. These characteristics may include the video or audio frequency composition of the first host signal.

the first data signal, on an error detection technique, or some other technique. In some implementations, the method further includes the step of: (8) determining a second error rate of the first extracted data signal at a time subsequent to determining the first error rate. In these implementations, step (2) is based, at least in part, on applying one or more statistical measures to the first and second error rates.

The above aspects and implementations of the present invention are not necessarily inclusive or exclusive of each other and may be combined in any manner that is non-conflicting and otherwise possible, whether they be presented in association with a same, or a different, aspect or implementation of the invention. The description of one aspect is not intended to be limiting with respect to other aspects. In addition, any one or more function, step, operation, or technique described elsewhere in this specification may, in alternative aspects, be combined with any one or more function, step, operation, or technique described in the summary. Thus, the above aspects are illustrative rather than limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the present invention will be more clearly appreciated from the following detailed description when taken in conjunction with the accompanying drawings, in which like reference numerals indicate like structures or method steps and in which the leftmost one or two digits of a reference numeral may indicate the number of the figure in which the referenced element or step first appears (for example, the element 220 appears first in Figure 2; the element 1090 first appears in Figure 10), and wherein:

Figure 1A is a functional block diagram of one embodiment of an information-embedding modem system, including an information-embedding modulator that is coupled to the head end of a cable network and a plurality of information-embedding demodulators coupled to user ends of the cable network;

Figure 1B is a graphical representation of a conventional cable plant;

Figure 1C is a graphical representation of a cable plant such as may be provided by the information-embedding modulator of Figure 1A to the head end of the cable network;

Figure 2 is a functional block diagram including one embodiment of the information-embedding modulator of Figure 1A and one embodiment of an illustrative one of the information-embedding demodulators of Figure 1A;

Figure 3 is a functional block diagram including another embodiment of the information-embedding modulator of Figure 1A and another embodiment of an illustrative one of the information-embedding demodulators of Figure 1A;

Figures 4A-4C are functional block diagrams of illustrative embodiments of data sources that may provide data signals to the information-embedding modulator of Figure 1A;

Figure 5 is a functional block diagram of one embodiment of television sources that may provide television signals to the information-embedding modulator of Figure 1A;

Figure 6A is a functional block diagram of one embodiment of the information-embedding demodulator of Figure 1A;

Figure 6B is a functional block diagram of another embodiment of the information-embedding demodulator of Figure 1A;

Figure 6C is a functional block diagram of one embodiment of the information-embedding demodulator of Figure 1A providing extracted data to illustrative embodiments of data and television receivers;

Figure 7 is a functional block diagram of one embodiment of a backward-compatible modem system;

Figure 8 is a flow chart of one embodiment of method steps and decision elements of backward-compatible modulation and demodulation;

Figure 9A is a simplified graphical representation of a single neighborhood of a conventional multi-drop cable system;

Figure 9B is a simplified graphical representation of two neighborhoods of a conventional multi-drop cable system;

Figure 10A is a simplified graphical representation of a neighborhood served by virtual-node cable distribution; and

Figure 10B is a graphical representation of a cable plant including one embodiment of virtual nodes of the virtual-node cable distribution of Figure 10A.

DETAILED DESCRIPTION

Attributes of the present invention, and of its underlying method and architecture, will now be described in detail with reference to the illustrative systems of Figures 1A, 1C, 2-7, 10A, and 10B, and the flow chart of Figure 8.

In this detailed description, references are made to various functional modules of information-embedding modem systems. Any of these functional modules, or portions thereof, may be implemented in hardware; on computer systems either in software, hardware, and/or firmware; or any combination thereof. It will be understood by those skilled in the relevant art that a functional module implemented in software typically comprises sets of software instructions that cause the described functions to be performed. It also will be understood that the functions ascribed to a module, when implemented on a computer in software, hardware, and/or firmware, typically are performed by a processor such as a special-purpose microprocessor or digital signal processor, program-logic controller, or by the central processing unit (CPU) of a computer system. Henceforth, the fact of such cooperation between any of such processor or controller and the modules of the invention may therefore not be repeated or further described, but will be understood to be implied. Moreover, the cooperative functions of an operating system, if one is present, may be omitted for clarity as they are well known to those skilled in the relevant art.

The System of Figure 1A

Figure 1A is a functional block diagram of one embodiment of an information-embedding (IE) modem system, referred to as IE modem system 100. IE modem system 100 modulates and demodulates television signals so that data may respectively be embedded in and extracted from those signals using techniques commonly referred to as "digital watermarking," "information hiding," "data hiding," or "steganography." For convenience, these techniques are hereafter simply referred to as "IE techniques" and the functions performed according to these techniques are referred to as "IE embedding" or "IE extracting." Systems that implement these techniques or functions may be referred to as "IE systems."

A key aspect of IE techniques is that data, in the form of components of one or more "watermark" signals, are embedded in one or more "host" signals by changing the values of components of the host signals. Typically, but not necessarily, the host signals are not changed enough to be noticeable to a user or to otherwise interfere with their use.

For example, the video portion of a television signal may be a host signal. The components of this host signal could correspond, for example, to the pixels of each field of a video image. The values of the components in this example could be the values of the pixels as measured by intensity, hue, and/or any other of their characteristics. Data may be embedded in this host signal by changing the characteristics of selected components. The result is what is referred to herein as a "composite" signal, meaning a signal that corresponds to the host signal, but with perturbations in the values of some host-signal components due to the embedding of the watermark signal in them. Thus, if the composite signal is to be transmitted, transmission generally does not require more bandwidth than would be required for the host signal. That is, using an example of embedding a digital watermark signal in a digital host signal, the quantity of data in the composite signal is the same as the quantity of data in the host signal, although the values of some data have been changed by the embedding process. Moreover, the embedding of data does not eliminate or replace the host signal to the extent that the essential information in the host signal is lost. The essential information of the host signal is present, although it has been altered, generally in imperceptible ways, to form the composite signal.

The watermark signal is extracted from the composite signal by determining how the composite-signal components differ from the values of the host signal components that would be expected if embedding had not been done. The difference typically is assumed to be due to a combination of the perturbations introduced by the embedding process and the effects of noise that has been added in transmission or at various points in the embedding or extracting processes.

A number of types of IE systems are known. One technique for IE embedding, referred to herein as "quantization index modulation (QIM)," is described by the inventors of the present invention in "System, Method, and Product for Information Embedding Using An Ensemble of Non-Intersecting Embedding Generators," International Application published under the Patent Cooperation Treaty, publication WO 99/60514 (November 25, 1999) (hereafter referred to as the "QIM PCT Application"). This technique is also described in articles authored by the present inventors entitled "Provably robust digital watermarking," Proceedings of SPIE: Multimedia systems and Applications II, Vol. 3845 (1999); and "Dither modulation: a

new approach to digital watermarking and information embedding," Proceedings of SPIE: Security and Watermarking of Multimedia Contents, Vol. 3657 (1999).

Other IE techniques, such as low-bit modulation and additive spread-spectrum modulation, are described in the QIM PCT Application and also in various sources including F. Hartung and M. Kutter, "Multimedia Watermarking Techniques," Proceedings of the IEEE: Special Issue On Identification and Protection Of Multimedia Information, Vol. 87, No. 7 (B. Macq, editor; July 1999) at 1079; F.A.P. Petitcolas, R.J. Anderson, and M.G. Kuhn, "Information Hiding -- A Survey," Proceedings of the IEEE: Special Issue On Identification and Protection Of Multimedia Information, Vol. 87, No. 7 (B. Macq, editor; July 1999) at 1062; and M.D. Swanson, M. Kobayashi, and A.H. Tewfik, "Multimedia Data-Embedding and Watermarking Technologies," Proceedings of the IEEE, Vol. 86, No. 6, June 1998, at 1064.

In order to avoid confusion, it may be noted that the words "embedding" or "extracting," and grammatical variations thereof, are sometimes used to describe techniques that are not IE techniques as commonly understood by those of ordinary skill in the art of information embedding, and as generally described above. For example, in the Ciciora article noted in the Background section above, reference is made to "recent efforts to embed data in analog television signals," and to "extracting the digital signal out of the analog signal" (at pages 1 and 3, respectively). Those references to "embed[ding]" and "extracting" are to the VBI, overscan, and sub-video techniques described above. As noted, these techniques involve inserting data into unused or visually inaccessible portions of a video signal or unused frequencies of a television channel, or replacing a portion of a video signal with data. They are not IE techniques, in which a watermark signal is embedded into a host signal.

Hereafter, the words "embedding," "extracting," and grammatical variations thereof will be used only in the sense they are used in relation to IE techniques or IE systems, such as, for example, "embedding" a watermark signal in a host signal to form a composite signal, and "extracting" a received data signal corresponding to the original watermark signal from the composite signal. Similarly, the word "watermark," and grammatical variations thereof, will be understood to refer to the function of embedding watermark signals in a host signal in accordance with any of the variety of presently known IE techniques, or IE techniques that may be developed in the future. Thus, for example, an information embedder that is said to embed a data signal into a host signal to

generate a composite signal comprising a watermarked version of the host signal will be understood to have performed this embedding function in accordance with any conventionally known or future IE techniques or IE systems.

Although the illustrated IE modem system 100 provides both modulation and demodulation, the invention is not so limited. Rather, aspects of the invention may be implemented in which only modulation, or only demodulation, functions are performed. For example, although IE modem system 100 of Figure 1A includes both IE modulator 110 and IE demodulators 120A-N (generally and collectively referred to as IE demodulators 120), an aspect of the invention could be IE modulator 110 without IE demodulators 120, or one or more of demodulators 120 without IE modulator 110.

As shown in Figure 1A, input to IE modulator 110 includes television signals 162 and data signals 172. IE modulator 110 selects one or more of television signals 162 to be host signals and modulates them by embedding in them one or more of data signals 172, thereby generating composite signals. As described in greater detail below with respect to Figures 2 and 3, IE modulator 110 also typically multiplexes the composite signals with those of television signals 162 that have not been watermarked (referred to herein as "non-host signals") so that the multiplexed signals may be transmitted over a cable network in accordance with conventional techniques. Two illustrative multiplexed signals, head-end multiplexed signals 112X and 112Y, are shown in Figure 1A as being provided by IE modulator 110 to cable network 199. As noted above, head-end multiplexed signals are typically provided over a common cable to a neighborhood served by the cable network. For example, it is illustratively assumed that head-end multiplexed signals 112X are transmitted over a cable X (not shown) to serve neighborhood X, and that head-end multiplexed signals 112Y are transmitted over a cable Y (not shown) to serve neighborhood Y. It will be understood that any number of head-end multiplexed signals, generally and collectively referred to as head-end multiplexed signals 112, may be provided to the cable network, typically to serve that number of neighborhoods.

The head end of a cable network typically comprises a "cable modem termination system (CMTS)." The CMTS transmits the head-end multiplexed signals to their corresponding neighborhoods over appropriate cables. The CMTS also may receive information back from the users by means of data transmitted over the return channel (such as return channel 161 of Figure 1B). According to some proposals, user

information may also be transmitted back to the CMTS in portions of the conventional cable plant other than the return channel. Examples of these proposals are described in the Henderson patent referred to above and in U.S. Patent No. 5,528,582 by Bodeep, *et al.* Hereafter, operations of illustrative cable network 199 will be described primarily in terms of the "downstream" transmissions from CMTS 130 at the head-end of the network to various user-ends serving IE demodulators 120. It will be understood, however, that "upstream" transmissions also typically occur between these user ends and CMTS 130.

Cable network 199 is graphically represented in simplified form in Figure 1A. CMTS 130 of cable network 199 receives head-end multiplexed signals 112 and routes and transmits them over cables corresponding to their respective intended neighborhoods. As will be described in greater detail below, IE modulator 110 may be used with a virtual node distribution system, or with a distribution system combining conventional multi-drop, as well as virtual node, approaches. In Figure 1A, the multiplexed signals transmitted over cable communication channel 140 to neighborhoods X and Y are represented by signals 132X and 132Y, respectively. Cable communication channel includes cables X and Y.

Cable network 199 typically also includes various channel noise sources 150 that introduce channel noise components 152 into channel 140. Channel noise components 152 generally are added to signals 132X and 132Y in ways known to those skilled in the relevant art. Channel noise components 152 may be introduced into the network from external sources, such as power lines or other electromagnetic sources in the external environment, or from fiber optic and/or coaxial wire cables, switches, relays, or other components of cable network 199. At the user ends of cable network 199, the transmitted multiplexed signals, with any noise components that may have been introduced, are coupled to the user ends. Examples are user-end multiplexed signals 142X and 142Y, representing what are generally and collectively referred to as user-end multiplexed signals 142.

In a typical cable network there are many user ends, *e.g.*, a user end corresponding to each of homes 901 in Figure 9A. It is assumed for illustrative purposes in Figure 1A that there are a number N of user ends in IE modem system 100, each of which is coupled to one of IE demodulators 120A-120N. IE demodulator 120A is shown as receiving user-end multiplexed signals 142X, indicating that it is served by cable X

and thus is in neighborhood X. IE demodulator 120N is shown as receiving user-end multiplexed signals 142Y, indicating that it is served by cable Y and thus is in neighborhood Y. In an alternative example, IE demodulators 120A and N could have been shown as being served by the same cable, and thus by the same one of user-end multiplexed signals 142, such as 142X or 142Y.

IE demodulators 120 provide at their outputs television signals 122 and extracted data signals 124. Television signals 122 are typically provided to one or more television receiver 180. Extracted data signals 124 are typically provided to one or more data receiver 190, such as a computer. Extracted data signals 124 correspond to data signals 172 that were embedded by IE modulator 110 into host television signals. Television signals 122 correspond to these host television signals, as well as to other of television signals 162 that were not hosts to embedding (*i.e.*, non-host signals). The operations by which IE modulator 110 and IE demodulators 120 accomplish these operations in two illustrative embodiments are now described with respect to the systems of Figures 2 and 3.

The System of Figure 2: IE Modulator 110

Figure 2 is a functional block diagram of one implementation of IE modulator 110 connected through cable network 199 to one implementation of IE demodulator 120A at one illustrative user end. IE modulator 110 of Figure 2 includes a host signals selector and optional de-multiplexer 210 (hereafter, simply selector 210) that selects one or more of television signals 162 to be host signals, referred to as host signals 212. In the illustrated implementation, selector 210 selectively directs for further processing host signals 212 and those of television signals 162 that were not selected to be host signals, referred to as non-host signals 216. Selector 210 also optionally de-multiplexes television signals 162 when they are received in multiplexed form. Another element of IE modulator 110 is information embedder 220 that receives host signals 212 from selector 210 and uses any known or future IE technique to embed one or more of data signals 172 into the host signals, thereby generating composite signals 222. In the illustrated implementation, IE modulator 110 includes data rate selector 225 that selects a data rate and provides this information to information embedder 220 so that it may embed data at the selected data rates. IE modulator 110 further includes broadcast format transformer 240 that, in the illustrated implementation, receives composite signals 222 from information embedder 220 and non-host signals 216 from selector 210 and

transforms signals 222 and 216 into a broadcast format. Also included in the illustrated implementation of IE modulator 110 is multiplexer and broadcast-band transformer 230 (hereafter, simply multiplexer 230). Multiplexer 230 multiplexes signals received from broadcast format transformer 240 and may also transform them into a broadcast band. The functions of each of these elements of IE modulator 110 are now described in greater detail.

Selector 210. As noted, selector 210 of the illustrated implementation optionally de-multiplexes television signals 162, selects one or more of television signals 162 to be host signals, and, in the illustrated implementation, selectively directs the host and non-host signals for further processing. Figure 5 is a functional block diagram that illustrates some of the various ways in which television signals 162 may be made available to IE modulator 110 and thus operated upon by selector 210. In one configuration, individual ones of television signals 162 are separately coupled to IE modulator 110 and thus to selector 210. For example, as shown in Figure 5, individual television signals 162A, B and N from television sources 160A, B, and N, respectively, may be provided to IE modulator 110 and thus to selector 210 as indicated in Figure 2 by the data-flow line labeled television signals 162. In this configuration, optional de-multiplexing is not undertaken because the signals are not multiplexed. Alternatively, one or more of television signals 162 may be provided to IE modulator 110 in multiplexed form. This alternative is illustrated in Figure 5 by the dotted lines representing multiplexer 550 and by the dotted-line multiplexed television signals 162A, B & N that are provided by multiplexer 550 to IE modulator 110. If television signals 162 are provided to IE modulator 110 in multiplexed form, then typically it is convenient that selector 210 de-multiplexes them, *i.e.*, separates them into individual signals, for further processing. In some configurations, some of television signals 162 may be provided to IE modulator 110 in multiplexed form and others of television signals 162 as individual signals. In these configurations, it also typically is convenient for selector 210 to de-multiplex the multiplexed signals.

As represented in Figure 5 by modulator 510, one or more of television signals 162 may itself have been modulated by a modulator that may, but need not, be an IE modulator. For example, modulator 510 may be an IE modulator that generates television signal 162A by embedding data 520 into the video and/or audio portion of television signal 512. Data 520 may be, for example, enhanced or interactive television

data. In the case of enhancement, data 522 could be extracted using an IE demodulator, *e.g.*, as described below with reference to IE demodulator 120A, to enable a television receiver to enhance the video signal. In the case of interactive data, data 522 could be data intended to be displayed to a user in response to a user command or selection. This user-display data may also be extracted in accordance with the operations of, for example, IE demodulator 120A. Data 522 may be any other kind of data, and modulator 510 may be a modulator that does not use IE techniques, such as one that inserts data into the VBI of the video portion of television signal 512. It generally is not material to the operations of IE modulator 110 or IE demodulator 120A whether one or more of television signals 162 has already been modulated as noted with respect to television signal 162A. In particular, IE modulator 110 generally may use television signal 162A as a host signal into which to embed data in the same manner as it may use any other of television signals 162, and IE demodulator 120A generally may extract data from a composite signal corresponding to television signal 162A in the same manner as it may extract data from any other host signal.

Selector 210 selects one or more of television signals 162 to be host signals into which to embed one or more of data signals 172 in any combination. For example, one data signal, or a portion thereof, may be embedded into one or more host signals; or two or more data signals, or portions thereof, may be embedded into one host signal. These selection functions correspond to method step 805 and decision elements 815 and 817 as represented in Figure 8. Figure 8 is a flow chart of one embodiment of method steps and decision elements of backward-compatible modulation and demodulation. Aspects of the operations of the system of Figure 2 also correspond to method steps and decision elements of Figure 8. These corresponding steps and elements hereafter will simply be referred to parenthetically.

Selector 210 may employ a variety of criteria to select the one or more host signals. Some criteria may be related to the operation of a "virtual node" system of data distribution at the user ends of cable network 199, as shown in the simplified illustrative embodiments of Figures 10A and 10B. A "virtual node" approach may be implemented in some aspects by the association of particular user ends with particular host signals so that some users served by a common cable on a multi-drop cable network obtain data by extraction from one or more host signals, while other users served by the same common cable obtain data by extraction from one or more other host signals. For example, it was

noted above in relation to Figure 9A that, in a conventional multi-drop network, homes 901A-E must share the approximately 27 Mbps data capacity of the common cable that serves their "neighborhood X." This capacity may be greatly expanded by employing IE techniques such that, for example, data to be transmitted to homes 901A and 901C are embedded in a first host signal of television signals 162, data to be transmitted to homes 901B and 901D are embedded in a second host signal of television signals 162, and data to be transmitted to home 901E are embedded in a third host signal of television signals 162. Thus, it may be said hereafter for convenience that homes 901A and 901C are in one virtual neighborhood served by a first virtual node 1050A, homes 901B and 901D are in another virtual neighborhood served by a second virtual node 1050B, and home 901E is in another virtual neighborhood served by a third virtual node 1050C. In accordance with this arrangement, as shown in Figures 10A and 10B, three virtual nodes or neighborhoods, corresponding to the three host signals, are created based on television signals transmitted over a single cable. Figure 10B is a graphical representation of an illustrative cable plant along frequency axis 1090 in which virtual node 1050A corresponds to a host signal in channel 172A, virtual node 1050B corresponds to a host signal in channel 172B, and virtual node 1050C corresponds to a host signal in channel 174A. Moreover, in alternative implementations, a virtual node or neighborhood need not be associated with only one host signal. Rather, two or more host signals may be used for embedding data to be transmitted to a particular group of homes.

In one aspect of the virtual node approach, selector 210 selects a host signal based on an existing association between a user end and a host signal. That is, the existing association may be "predetermined" in that it has been established or determined by a person (*e.g.*, it may be "user-selected"), by a system, or by a method operating externally to IE modulator 110. Data representing this predetermined association may be included, for example, in user information 174. In other implementations, the data could be stored in a data storage medium (not shown) included in IE modulator 110.

As one of many possible examples, it is assumed for purposes of illustration that user information 174 includes an association between home 901A and one of television signals 162. Because a television signal is typically multiplexed into a television channel as shown in Figures 1B and 1C, a channel reference may sometimes hereafter be used for convenience to identify a particular television signal in this context. For instance, it is illustratively assumed that home 901A is associated with analog television channel with

embedded data 172A (hereafter, simply "analog channel 172A") of Figure 1C. This association may be established in accordance with any of a variety of known techniques, such as by entries in a record of a data base (not shown) maintained in one of data sources 170 that includes, for example, a computer system. This data base may be accessed by selector 210, the entries may be conveyed to selector 210 from data sources 170, or other known techniques may be used to maintain and update the association.

The association between a user end, and a signal to be used as a host signal for embedding data intended for that user end, may further be refined. For example, home 901A may be associated with the video signal portion of the television signal transmitted in analog channel 172A or, alternatively or in addition, with the audio signal portion of that television signal. Moreover, home 901A may be associated with particular segments of those video and/or audio signal portions. Also, home 901A may be associated with one or more data signals in conventional data channel 166; that is, a data signal that typically is multiplexed to be located in channel 166 may serve as a host signal into which one or more of data signals 172 intended for transmission to home 901A may be embedded. Data signals 172 may themselves be the data signals that are multiplexed into data channel 166. A data signal of data signals 172 therefore may be embedded into another (or the same) data signal of data signals 172. Thus, television signals 162 may be considered also to include one or more of data signals 172 in some implementations.

In some implementations, associations between user ends and host signals may be initially established, and thereafter followed, by selector 210 based on one or more criteria, and/or they may be dynamically changed based on a variety of factors. For example, it is assumed for illustrative purposes that information embedder 220, described below, employs a particular IE embedding technique that embeds 10 Mbps of data in any selected one of analog channels 172 of Figure 1C and 20 Mbps of data in any selected one of digital television channels with embedded data 174 (hereafter, simply "digital channels 174") of Figure 1C. It is also illustratively assumed that selector 210 either randomly associated home 901A with analog channel 172A or that this association had otherwise been initially established and communicated to selector 210 via user information 174. It further is assumed that home 901C also has been initially associated with analog channel 172A. Homes 901A and 901C may thus for convenience be said to be receiving data over virtual node 1050A, as shown in Figure 10A. As another example, homes 901B and 901D may be assumed to be receiving data intended for them

(and distinguished from each other using packets or other conventional data distribution techniques) over analog channel 172B. Thus, homes 901B and 901D may be said to be receiving data over virtual node 1050B.

Homes 901A and 901C may each concurrently be engaged in downloading information, *e.g.*, data signals 172 from Internet data sources of data sources 170, at rates of 4 Mbps. The combined data usage of 8 Mbps is within the assumed 10 Mbps data capacity of virtual node 1050A. However, it is now assumed that home 901A sends information via return channel 161 indicating that it wishes to download data at a rate of 7 Mbps. If both of homes 901A and 901C remain associated with virtual node 1050A, then this request for additional data capacity cannot be fulfilled since the combined requested data capacity of 7 + 4 = 11 Mbps exceeds the assumed 10 Mbps capacity of analog channel 172A to carry embedded data. In such a case, selector 210 may change the association of home 901A with virtual node A and, for example, associate it with virtual node 1050B. This change of association may be accomplished in accordance with any of a variety of known techniques, such as by changing data entries in the data base referred to above or by changing pointers in a data base. For convenience, a change of association between a user end and a host signal, cr the establishment of an association in substantially real time, may be referred to hereafter as "dynamic association." Assuming that other homes that already are associated with virtual node 1050B are not consuming a combined data capacity of more than 3 Mbps, then home 901A's request for data capacity of 7 Mbps may be honored under this new association. Alternatively, selector 210 may dynamically associate home 901C with another virtual node (*i.e.*, another one or more host signals, or portions thereof) so that it is no longer associated with virtual node 1050A, thus leaving sufficient capacity on analog channel 172A to serve home 901A's request.

As another example, it is assumed that home 901A requests a data capacity of 12 Mbps, which exceeds the assumed data capacity of any of analog channels 172A. In such a circumstance, selector 210 may dynamically associate home 901A with one of digital channels 174A, having an assumed capacity of 20 Mbps, so that the request may be fulfilled. Alternatively, selector 210 may dynamically associate home 901A with both of analog channels 172A and 172B (or with any other combination of analog channels 172 and/or digital channels 174) so that a portion of the data to be transmitted to home 901A is embedded in, for example, the video signal present in analog channel

172A and another portion is embedded in the video signal present in analog channel 172B. In that illustrative case, home 901A is associated with virtual nodes 1050A and 1050B.

Another criterion that selector 210 may employ in assigning a user end to a virtual node (*i.e.*, in selecting a host signal to be associated with that user end, or, as in the present example, with one of homes 901) is the anticipated and/or determined signal-to-noise ratio of user-end multiplexed signals 142 as received at that user end. Signals 142 received at user ends that are closer to the head end of cable network 199 typically have higher signal-to-noise ratios than signals 142 received at user ends situated further away, even though all of these user ends may be in the same neighborhood, *i.e.*, they may be served by what has been referred to above as a common cable. The reason is that there typically is less path loss over a shorter length of cable. Moreover, as will be appreciated by those of ordinary skill in the relevant art, an IE embedder typically may embed more information in a signal having a high received signal-to-noise ratio than one having a lower received signal-to-noise ratio. Thus, a higher rate of embedding data (hereafter, simply a higher "data rate") may be employed to transmit embedded data to a user end that receives user-end multiplexed signals 142 with a high signal-to-noise ratio than to a user end that receives user-end multiplexed signals 142 with a low signal-to-noise ratio. Therefore, it may be advantageous for selector 210 to consider signal-to-noise ratio as a factor in assigning user ends to virtual nodes.

In particular, a "weak-link" affect may be avoided by assigning user ends to host signals based on similarity of signal-to-noise ratios of user-end multiplexed signals 142. For example, it is assumed that user-end multiplexed signals 142X are received at home 901A with a high signal-to-noise ratio and that home 901B receives user-end multiplexed signals 142X with a low signal-to-noise ratio. If homes 901A and 901B are both associated with the same virtual node, *e.g.*, the same host signal, then the data rate for that virtual node is constrained by the lower signal-to-noise ratio applicable to home 901B. Otherwise, as will be appreciated by those skilled in the relevant art, errors in data extraction may occur if data intended for home 901B is embedded at the higher rate at which data extraction can successfully be done at the higher signal-to-noise ratios experienced by home 901A. This weak-link affect is avoided if selector 210 associates home 901A with a virtual node associated with other homes that receive user-end multiplexed signals 142X at similarly high signal-to-noise ratios, and home 901B is

associated with a virtual node associated with homes that receive user-end multiplexed signals 142X at similarly low signal-to-noise ratios. In this manner, the rate at which data may be provided to all of homes 901 served by a common cable, *i.e.*, in conventional neighborhood X, generally is further increased.

Techniques by which signal-to-noise ratios may be anticipated and/or determined are described below in relation to the operations of data rate selector 225 and data rate analyzer 295A. For purposes of the operations of selector 210, it is sufficient to state that data regarding data rates of particular user ends (hereafter, "data-rate data") may be provided to selector 210 as components of data information 174 and/or they may be received over a return channel of cable network 199 as transmitted from the user ends (*e.g.*, from data rate analyzer 295A of illustrative IE demodulator 120A).

As will now be evident based on the foregoing description of selector 210, many variations are possible for initially and/or dynamically associating homes 901 with one or more video or audio signals of the television signals in any of channels 172 or 174. Also, data may be embedded in data included in conventional data channel 166. Thus, selector 210 may initially and/or dynamically associate any of homes 901 with any data signals in data channel 166.

The operation of selector 210 in "selecting" a host signal may thus, in some aspects, comprise the just-described operation of associating a user end with a television signal. For example, selector 210 may be said to have selected the video portion of the television signal in analog channel 172A to be the host signal in which data intended for home 901A is to be embedded by information embedder 220. Other types of selection are also possible, however. For instance, selector 210 may select a host signal for a particular user end based on sequential, random, or other assignment from among available television signals. Also, selector 210 may select a host signal based in part or in whole on a user selection. As one of many other possible examples, selector 210 may select a host signal based at least in part on a predetermined assignment of a host signal to a user end.

In addition, selector 210 may select a host signal based on characteristics of that signal. For example, selector 210 may determine from a look-up table based on prior analysis, by real-time signal analysis, or in accordance with various other known techniques, that a particular audio, video, or data signal of television signals 162 is particularly well suited for embedding certain types of data or for embedding data at a

particular rate. For example, a video signal having frequency components in a certain range, or having a certain combination of frequency components, may be particularly well suited for embedding data. This advantage may be due, for example, to characteristics of the human visual or auditory systems that enable data to be embedded at greater densities, or with greater robustness in the presence of noise, at certain frequencies or in the presence of certain frequency combinations.

In the implementation illustrated in Figure 2, host signals are provided to information embedder 220 and non-host signals are provided to broadcast format transformer 240 based on the selection of host signals made by selector 210. As will be evident to those skilled in the relevant arts, there are many conventional techniques by which host and non-host signals may be selectively routed in this manner. Alternatively, television signals 162 may be directly provided to information embedder 220 and broadcast format transformer 240 and they may select host and non-host signals for processing based on information provided by selector 210. For example, selector 210 may notify information embedder 220 of which one or more of the video, audio, and/or data portions of television signals 162 are to be the host signal for data to be transmitted to a particular user end. This notification may be accomplished in accordance with any of a variety of known techniques, such as by passing arguments in a subroutine or procedure call, changing variables in a data base, and so on.

To further illustrate the operation of IE modulator 110 in the configuration shown in Figure 2, it is now assumed that television signals 162 are provided to IE modulator 110 in a source format and in a base band. Alternative illustrative assumptions, *i.e.*, that television signals 162 are in a broadcast format and in a broadcast band, are described below in relation to the configuration of IE modulator 110 shown in Figure 3. The term "broadcast format" is used herein to mean that television signals 162 are in a format now used for television broadcast systems, such as the NTSC, PAL, SECAM, PAL-M, PAL-N, or MESECAM formats, or in any future format that may be adopted for television broadcast systems. One example of a "source format," as that term is used herein, is an RGB format such as may apply to the video portion of television signals provided by a video or television camera. A television signal originating in a source format typically is transformed to a broadcast format for broadcast to television receivers over any type of broadcast system including over-the-air, satellite, or cable system. The term "broadcast band" as applied to television signals 162 means that those signals have been

transformed from a "base band," *i.e.*, not modulated with a carrier signal, to various carrier frequencies depending on the modulation of each television signal with a different carrier frequency. Television signals 162 in a broadcast band thus typically are organized in a range of carrier frequencies such as the range of 50 MHz to 750 MHz shown with respect to conventional cable plant 169 of Figure 1B. Because television signals 162 are assumed in this example to be in a base band and in a source format, the ones selected by selector 210 to be host signals are referred to as base-band source-formatted host signals 212. The ones of television signals 162 not so chosen are similarly referred to as base-band source-formatted non-host signals 216.

Information Embedder 220. Information embedder 220 embeds data signals 172 into base-band source-formatted host signals 212 as selected by selector 210. (See corresponding method step 810 of Figure 8.) Data signals 172 may include data in any form. For example, data signals 172 may include digital data, which may have been converted to digital form from analog data. For instance, data signals 172 may include sampled data of an analog video signal. However, data signals 172 need not be in digital form; *e.g.*, they may include an analog signal. Also, it is not material to the present invention what kind of information is represented by data signals 172. For example, data signals 172 may include telephony data 412 such as are carried in a public switched telephone network, represented in Figure 4A by telephone network 410. As another of many possible examples, data signals 172 may include Internet data 422 such as HTML documents; audio, picture, or video files; text, data, or program files; and so on. Some examples of possible elements of data sources 170 are illustrated in Figure 4B.

Yet another example is illustrated in Figure 4C, in which a user 435 causes user-request data 437 to be sent to television server 430, as may occur, for example, over return channel 161. This request may be to view a television program, such as a movie or an archived episode of a television series. For convenience, a request of this type may be referred to as "video-on-demand," although it will be understood that the request may be to download audio as well as video data, or it may be to download other types of data. In Figure 4C, it is illustratively assumed that user-request data 437 specifies that television server 430, employing known techniques, download to user 435 a television program represented by television data 432. Television data 432 may be digital television data, or it may be analog television data and, in either case, is included in data signals 172 of the illustrated example.

As noted, information embedder 220 embeds one or more of data signals 172 into one or more of host signals 212 using any IE technique, or on any IE system, now known or that may be developed in the future. Conventional IE techniques typically do not change either the band or formatting of the host signals. Thus, the embedding function performed by information embedder 220 is indicated in the illustrated example as resulting in composite signals that are in a base band and in a source format, referred to as base-band source-formatted composite signals 222. As previously noted, embedding a data signal into a host signal by IE techniques may be said to produce a composite signal that is a watermarked version of the host signal.

Data rate selector 225. Data rate selector 225 selects data rates 227 for embedding data into host signals based on presumed (*e.g.*, based on default values) and/or determined signal-to-noise ratios over the cables of cable network 199. (See method step 803.) In addition, or in the alternative, selector 225 may select data rates 227 based on presumed or user-defined acceptable levels of distortion.

Data rate selector 225 provides data rates 227 to information embedder 220 so that it may embed data at the selected rates. Embedder 220 adjusts the rate at which it embeds one or more of data signals 172 into one or more of host signals 212 in accordance with known IE techniques. For example, with respect to the QIM technique referred to above, embedder 220 may increase the number of "watermark signal components," *i.e.*, components of data signals 172, that are embedded within a given number of host signal components. Examples of "components" of watermark and host signals are one or more bits of a binary number representing a value (such as gray-scale value) of a pixel in the watermark or host signal.

In the illustrated embodiment, data rate selector 225 selects a data rate for each of data signals 172 that is to be transmitted to one of IE demodulators 120. That is, for example, a first of data signals 172 is illustratively assumed to be intended to be transmitted to IE demodulator 120A and a second to IE demodulator 120B. Data rate selector 225 thus selects a first data rate 227 (hereafter, data rate 227A) at which embedder 220 embeds the first of data signals 172 into a host signal selected by selector 210 to be associated with IE demodulator 120A. Selector 225 selects a second data rate 227 (hereafter, data rate 227B) at which embedder 220 embeds the second of data signals 172 into a host signal selected by selector 210 to be associated with IE demodulator 120B.

As noted, data rates 227A and 227B may be based on presumed and/or determined signal-to-noise ratios. For example, these ratios may initially be presumed, *e.g.*, they may be set to default values that are based on known characteristics of cable network 199 or other factors. For instance, as noted above, the signal-to-noise ratio generally decreases in proportion to the length of the cable from the head end of cable network 199 to the user end. The approximate distance from the head end of cable network 199 to IE demodulator 120A typically is known, or may be determined by known techniques, and thus an initial estimate of the signal-to-noise ratio of user-end multiplexed signals 142X received at IE demodulator 120A may be made in accordance with known techniques. This estimate, hereafter referred to for convenience as a default value, may be an absolute one, or may be a relative one as compared to the length of cable serving other user ends, such as the user end at which IE demodulator 120B is located. A variety of factors other than length of cable, such as electromagnetic interference from sources external to cable network 199, may also contribute to the signal-to-noise ratio. Known techniques may be employed to predict, detect, and/or measure these factors and alter the default signal-to-noise ratios accordingly. In accordance with any of a variety of known techniques, these default signal-to-noise ratios may be stored by a user in a data base (not shown) and communicated to selector 225 as a portion of user information 174.

As noted, selector 225 may also take into account default or user-defined acceptable levels of distortion. For example, if these acceptable levels of distortion are high with respect to reception of user-end multiplexed signals 142X by IE demodulator 120A, then selector 225 may select a higher value for data rate 227A than might otherwise be selected. This relationship obtains because, in accordance with some IE techniques, greater reliability of data extraction may be realized, even at higher data rates, by introducing greater distortion due to the embedding process. Thus, acceptance of greater distortion may be traded off for increased data transmission in appropriate applications (such as, for example, where distortions are already present in television signals 162 or where a user or cable operator chooses to trade off distortion for increased data rates).

Typically, the initial and any subsequent values of data rate 227A are used by information extractor 290A of IE demodulator 120A in performing its information extraction function. Thus, in terms of the illustrated example, information extractor

290A is provided with access to an initial rate 227A-1 at which data is embedded and to any new rate 227A-2 thereafter selected by data rate selector 225. Initial rate 227A-1 may be included in optional selection data 214A so that rate 227A-1 is available to information extractor 290A, as described below with respect to the operations of composite signals selector and splitter 250A. Alternatively, a default value of initial rate 227A-1 may be predetermined and accessed in accordance with known techniques by both information embedder 220 and information extractor 290A. Any other of a variety of known techniques may be used to establish initial rate 227A-1 and to communicate this information to IE demodulator 120A. Moreover, information about changes in data rate 227A may be included by information embedder 220 in the data that it embeds for transmission to IE demodulator 120A. Thus, new rate 227A-2 may be embedded by information embedder 220A into the host signal associated with IE demodulator 120. In the same manner that information extractor 290A extracts extracted data signals 124A corresponding to data signals 172, as described below, it also extracts the value of new data rate 227A. Information extractor 290A may then apply new data rate 227A to subsequent extractions, or it may optionally engage in any of a variety of known synchronization procedures, using for example a return channel of cable network 199, to confirm that the new rate has been received and to provide a reliable transition from one value of data rate 227 to another. Alternatively, data rate analyzer 295A may select a new data rate and communicate that selection to data rate selector 225 over cable network 199 as part of data-rate data 297A.

Selector 225 may adjust data rates 227A based on information such as the signal-to-noise ratio measured or otherwise determined with respect to the communication channels. This information is represented by received data-rate data 298A of Figure 2, corresponding to transmitted data-rate data 297A. In the illustrated implementation, transmitted data-rate data 297A is transmitted from IE demodulator 120A to the head end of cable network 199 over a return channel. Any of a variety of other known techniques may be employed in other implementations in order to communicate transmitted data-rate data 297A. Transmitted data-rate data 297A is determined by data rate analyzer 295A of IE demodulator 120A in accordance with operations described below.

Data rate selector 225 need not be implemented in other implementations. For example, the rate at which information embedder 220 embeds data may be a predetermined constant value. However, advantages may be obtained by including

selector 225 so that it may select data rates based on various factors such as the signal-to-noise ratio anticipated and/or experienced with respect to a particular communication channel. As noted, the larger the signal-to-noise ratio, the greater the rate at which data may be embedded by information embedder 220 without increasing the likelihood of error. Thus, for example, data rate analyzer 295A may detect a decrease in channel noise components 152 as received in user-end multiplexed signals 142X and increase the value of transmitted data-rate data 297A accordingly. Consequently, data rate selector 225 may select a higher value for data rate 227A so that the amount of data transmitted to IE demodulator 120A is increased. Similarly, an increase in channel noise detected by data rate analyzer 295A may result in a lower value for data rate 227A and a decrease in the amount of data transmitted to IE demodulator 120A. Based on this lower data rate, selector 210 may associate IE demodulator 120A to another virtual node, thereby avoiding the "weak-link" affect noted above.

Broadcast format transformer 240. Transformer 240 applies any known transformation technique, or one that may be developed in the future, to transform base-band source-formatted non-host signals 216 and base-band source-formatted composite signals 222 into a broadcast format. (See decision element 820 and method step 822.) For example, signals 216 and 222 may be transformed into the NTSC format. In the illustrated embodiment, transformer 240 provides the transformed signals, referred to as base-band broadcast-formatted non-host signals 217 and base-band broadcast-formatted composite signals 223, to multiplexer and broadcast-band transformer 230.

Multiplexer and broadcast-band transformer 230. Transformer 230 applies any known transformation technique, or one that may be developed in the future, to transform base-band broadcast-formatted non-host signals 217 and base-band broadcast-formatted composite signals 223 into a broadcast band. (See decision element 824 and method step 826.) Also in accordance with known or future techniques, signals 217 and 223 are typically multiplexed. (See decision element 827 and method step 830.) The resulting multiplexed and transformed signals are referred to hereafter for convenience as "head-end multiplexed signals," such as represented in Figure 2 by head-end multiplexed signals for neighborhood X 112X (hereafter, simply head-end multiplexed signals 112X). As will be appreciated by those skilled in the relevant art, the transformation functions and multiplex function described above with respect to transformers 240 and 230 may be performed in various combinations or orders and/or may be represented as

being performed by a single processor. Also, the multiplexing function of transformer 230 may be performed by an additional functional element, *i.e.*, a multiplexer, that may, but need not, be included in IE modulator 110.

The System of Figure 2: IE Demodulator 120A

As noted with respect to Figure 1A, IE demodulator 120A is an illustrative one of IE demodulators 120. IE demodulator 120A is coupled to a user end of cable network 199 to receive user-end multiplexed signals 142X, which correspond to head-end multiplexed signals 112X plus any channel noise components 152 that may have been introduced. (See method step 835.) For convenience, references to the user end at which IE demodulator 120A is located (*i.e.*, the user end at which IE demodulator 120A is operated) will be made simply by referring to IE demodulator 120A.

Various embodiments of IE demodulator 120A are possible. In the embodiment shown in Figure 2, IE demodulator 120A includes composite signals selector and splitter 250A that splits signals 142X into two paths, selects received broadcast-band composite signals 252A from user-end multiplexed signals 142X, and separates signals 252A from signals 142X for further processing, all in accordance with known techniques. Composite signals 252A correspond to those of host signals 212 that are associated by selector 210 with IE demodulator 120A; that is, the host signals into which data intended for IE demodulator 120A are embedded. Also included in IE demodulator 120A of the illustrated embodiment is broadcast-band to base-band transformer 270A that transforms received broadcast-band composite signals 252A to a base band, thereby generating base-band broadcast-formatted received composite signals 272A. In the illustrated embodiment, broadcast-format to source-format transformer 280A also is included in IE demodulator 120A to transform base-band broadcast-formatted received composite signals 272A to a source format, thereby generating base-band source-formatted received composite signals 282A. Information extractor 290A of IE demodulator 120A employs IE techniques to extract extracted data signals 124A from source-formatted received composite signals 282A. Extracted data signals 124A correspond to one or more of data signals 172 that were intended to be transmitted to IE demodulator 120A (*i.e.*, to the user end at which IE demodulator 120A is located). Data rate analyzer 295A of IE demodulator 120A analyzes data signals extracted by information extractor 290A in order to determine a rate for embedding data. Yet another functional element that optionally may be included in IE demodulator 120A is television signal processor 285A

that may apply any of a number of known processes to prepare signals for use by a television receiver. In some implementations, any one or more of these processes may be performed by functional elements that are not included in IE demodulator 120A. For example, they may be performed by television receiver 180A.

It will be understood that, as with respect to IE modulator 110, the aforementioned functions of IE demodulator 120A may, in alternative implementations, be performed in other orders, *e.g.*, the operations of transformer 280A may be performed before those of transformer 270A. Functions may be combined to be performed by fewer functional elements, or separated to be performed by additional functional elements. Also, the transformations of transformers 270A and/or 280A need not be performed in some implementations so that information extractor 290A operates on untransformed, or partially transformed, signals. The operations of the illustrative functional elements shown in Figure 2 are now described in greater detail.

<u>Composite signals selector and splitter 250A</u>. As noted, composite signals selector and splitter 250A selects received broadcast-band composite signals 252A from user-end multiplexed signals 142X. (See method step 840 and decision element 845.) That is, in the illustrated implementation, selector and splitter 250A identifies the particular one or more of host signals 212 associated with IE demodulator 120A and thereby identifies the received broadcast-band composite signals 252A that correspond to those host signals. Selector and splitter 250A optionally separates signals 252A from others of user-end multiplexed signals 142X so that signals 252A may be further processed by transformers 270A and 280A and by information extractor 290A. Selector and splitter 250A performs these functions in accordance with any of a variety of known or future techniques for identifying signals and splitting or demultiplexing them.

For example, the identification function may be performed in accordance with a variety of known techniques for synchronizing and maintaining information in a distributed data base or generally among nodes of a network. In accordance with one known technique, each video and audio signal of television channels 168 and 164, as well as the one or more data signals in data channel 166, has a unique signal identifier. Selector 210 selects host signals 212 in the manner described above. In particular, it is assumed for illustrative purposes that selector 210 associates IE demodulator 120A with the video portion of the television signal in analog channel 172A of Figure 1C. Thus, IE demodulator 120A (or, alternatively viewed, an associated user end, such as home 901A

for example) is associated with the signal identifier of that video signal. For illustrative purposes, the carrier frequencies of the video and audio portions of the television signal in analog channel 172A are shown in Figure 1C where those video and audio signals are respectively provided the illustrative signal identifiers "VS1" and "AS1." In the present example, the signal identifier VS1 therefore is associated with IE demodulator 120A. This association, as noted above with respect to the operations of selector 210, may be maintained in a database or in accordance with other known or future techniques.

More generally, associations between the signal identifiers of the selected host signals 212 and their respective user ends are represented in Figure 2 as selection data 214. That is, selection data 214 of the illustrated implementation include data that associates each user end with one or more host signals into which data to be transmitted to that user end is embedded. In terms of the present example, data 214 includes information that associates IE demodulator 120A with signal identifier VS1. This association indicates that data intended to be transmitted to IE demodulator 120A is embedded in the host signal identified by the signal identifier VS1. As noted above, data 214 may also include information about the rate at which data intended to be transmitted to IE demodulator 120A is embedded.

In the illustrated implementation, data 214 may be provided by selector 210 to information embedder 220 and/or optionally (as indicated by dotted data-flow line 214A) to cable network 199. More specifically with respect to the latter option, selector 210 provides data 214A to CMTS 130 of cable network 199. CMTS 130, in accordance with known techniques such as handshaking techniques, transmits data 214A over cable network 199 to IE demodulators 120. With respect to the present example, when communication over cable network 199 is initiated with IE demodulator 120A, a handshaking procedure may be performed that informs selector and splitter 250A that, for example, the signal having the signal identifier VS1 is the host signal for embedding data intended for IE demodulator 120A. Selector and splitter 250A may then employ any of a variety of known techniques to select received broadcast-band composite signals 252A from user-end multiplexed signals 142X. For example, the signal identifier VS1 may be associated using hardware, firmware, software, or any combination thereof with a multiplexed signal having a particular carrier frequency. In some implementations, this association may be predetermined so that, for instance, VS1 refers to the video signal in the analog television channel referred to in Figure 1C as analog channel 172A.

Generally, the arrangement of multiplexed signals in user-end multiplexed signals 142X is the same as the arrangement of multiplexed signals in head-end multiplexed signals 112X. Thus, the signal identifier VS1 indicates to selector and splitter 250A that composite signals 252A in the present example includes the video signal in the channel of user-end multiplexed signals 142X corresponding to analog channel 172A of head-end multiplexed signals 112X.

As an alternative, or in addition, to the optional procedure just described with respect to optional selection data 214A, other procedures may be used so that selector and splitter 250A may initially select composite signals 252A having embedded data intended for IE demodulator 120A. For example, a particular video, audio, or data signal of television signals 162, or any combination of one or more of them or portions thereof, may be predetermined to be the host signal into which data is embedded for the user end at which IE demodulator 120A is located. For instance, it may be predetermined that IE demodulator 120A is associated with the audio signal having the signal identifier AS1 and that signal AS1 is multiplexed so as to have a predetermined carrier frequency. This predetermined association may be established or changed in accordance with any of a variety of known or future techniques.

There are many other techniques by which selector and splitter 250A may initially select composite signals 252A. For example, a particular video, audio, or data signal of television signals 162, or any combination of one or more of them or portions thereof, may be predetermined to be embedded with selection data 214. For example, it may be predetermined that information embedder 220 embeds selection data 214 into a predetermined one or more signals multiplexed into conventional data channel 166. In this implementation, selector and splitter 250A selects and splits this predetermined signal so that it optionally is transformed by transformers 270A and 280A (*i.e.*, one or both transformations may not be performed in some embodiments) and is provided to information extractor 290A, as shown in Figure 2 and further described below. In this implementation, extractor 290A extracts selection data 292A and provides this information to selector and splitter 250A. Selection data 292A may indicate, for example, that IE demodulator 120A is associated initially with the host signal identified by signal identifier VS1. Thus, selector and splitter 250A selects received broadcast-band composite signals 252A to be the one of user-end multiplexed signals 142X having a carrier frequency identified by the signal identifier VS1.

As noted above, selector 210 may determine that the association of IE demodulator 120A with one or more of host signals 212 should be changed. This change may be undertaken, for example, to change the virtual node with which IE demodulator 120A is associated so that the amount of data provided to IE demodulator 120A may be increased, or for other reasons such as those described above with respect to the operations of selector 210. In the illustrated implementation, selector 210 modifies selection data 214 to indicate this change of host signals for IE demodulator 120A. Selection data 214 is provided by selector 210 to information embedder 220. Information indicating the change of host signals for IE demodulator 120A therefore is embedded in received broadcast-band composite signals 252A and extracted by information extractor 290A as herein described. Information extractor 290A provides this revised selection data 292A to selector and splitter 250A that therefore performs its selection and splitting functions, in accordance with known techniques such as de-multiplexing techniques, to select a different received broadcast-band composite signals 252A.

As one illustrative example of this technique for changing host signals (*i.e.*, in some implementations, for changing virtual nodes), it is assumed that, initially, signals 252A consist of a received broadcast-band composite signal corresponding to host signal VS1. Embedder 220 subsequently embeds into host signal VS1 a portion of selection data 214 indicating that selector 210 has changed the association of host signals for IE demodulator 120A so that host signal AS1 is the new host signal into which data intended for IE demodulator 120A will be embedded. As just described, selector and splitter 250A selects the initial signals 252A consisting of a received broadcast-band composite signal corresponding to host signal VS1 and provides that composite signal for optional processing by transformers 270A and 280A and by extractor 290A. Extractor 290A extracts the information that the corresponding host signal has been changed from VS1 to AS1 and, as indicated by selection data 292A, informs selector and splitter 250A of this change in accordance with known techniques. Consequently, selector and splitter 250A henceforth selects composite signals 252A consisting of a received broadcast-band composite signal corresponding to host signal AS1. In some implementations, a handshaking procedure may be employed prior to implementing the change of host signals from VS1 to AS1 so that IE demodulator 120A confirms with selector 210 that the change of host signals has been accurately received. For example,

selector and splitter 250A may cause this confirming information to be transmitted via return channel 161 over the coupling between IE demodulator 120A and its user end of cable network 199. A further change of host signal may be implemented by, for example, including the further change in the portion of selection data 214 embedded into host signal AS1. This process, with or without confirmation, may be repeated indefinitely.

Transformers 270A and 280A. As noted with respect to the illustrated embodiment, broadcast-band to base-band transformer 270A transforms received broadcast-band composite signals 252A to a base band, thereby generating base-band broadcast-formatted received composite signals 272A. Broadcast-format to source-format transformer 280A receives base-band broadcast-formatted received composite signals 272A from transformer 270A and transforms them to a source format, thereby generating base-band source-formatted received composite signals 282A. Typically, the source format is the same source format in which base-band source-formatted host signals 212 were formatted. Any of a variety of known techniques, or ones to be developed in the future, may be employed by transformers 270A and 280A to perform these functions. (See corresponding decision element 847 and method step 850 of Figure 8.) As also noted, the functions of transformers 270A and 280A may be performed in a different order, combined, or otherwise implemented in accordance with known or future techniques.

Information Extractor 290A. In the illustrated implementation, information extractor 290A receives base-band source-formatted received composite signals 282A from transformer 280A. In other implementations, extractor 290A may operate on signals provided by transformer 270A or selector and splitter 250A, that is, as noted, either or both of the functions of transformers 270A and 280A may be omitted. Information extractor 290A employs any known or future IE technique to extract extracted data signals 124A from, in the illustrated implementation, source-formatted received composite signals 282A. (See method step 855.) Extracted data signals 124A, corresponding to those of data signals 172 that were intended to be transmitted to IE demodulator 120A, are provided by extractor 290A to data receiver 190A and to data rate analyzer 295A.

Figure 6C is a functional block diagram that shows some illustrative examples of couplings that may be made to various types of data receiver 190A. For example, IE

demodulator 120A may be coupled to two personal computers, PC1 and PC2, that are shown as data receivers 190A-1 and 190A-2. In terms of the illustrated implementation of Figure 2, information extractor 290A provides to data receivers 190A-1 and 190A-2 extracted data signals 124A-1 and 124A-2, which may be data in any form such as text, image, video, audio, HTML, or application files. Another example of a type of data signals 124A that may be extracted is telephony data 124A-3 that, as indicated by data receiver 190A-3, may be provided to a telephone receiver, answering machine, voice mail system, or other telephony device. Yet another of many possible examples is illustrated by data receiver 190A-4 for receiving stereo audio data 124A-4.

Television Signal Processor 285A. Extracted data signals 124A may also be video and audio signals of one or more television signals. That is, one or more of television signals 162 may be embedded into one or more host signals. Data corresponding to those embedded television signals may be extracted by IE demodulator 120A to yield extracted data signals 124A-5 corresponding to the embedded television signals. (Extracted data signals 124A-5 are shown as a dotted line in Figure 2 to indicate that none of television signals 162 need be embedded; *i.e.*, there need not be any extracted data signals 124A-5.) Extracted data signals 124A-5 in some implementations may be provided directly to a television receiver. In other implementations, extracted data signals 124A-5 may be additionally processed in any one, or combination, of a variety of known ways such as by demultiplexing, converting digital television data to an analog television signal, selecting and/or blocking television signals according to a user's subscription to the cable service, applying enhancement techniques to the video or audio portions, and so on. Any one or more of these functions are represented in Figure 2 by television signal processor 285A.

In addition to processing extracted television signals, television signal processor 285A may be employed to similarly process any or all of user-end multiplexed signals 142X and provide the processed signals, represented in Figures 1 and 2 by television signals 122A, to television receiver 180A. In implementations in which processor 285A is not employed, or its functions are performed by television receiver 180A, user-end multiplexed signals 142X and television signals 122A may be the same signals; *i.e.*, user-end multiplexed signals 142X may be provided directly to television receiver 180A. In either case, television signals 122A correspond with television signals 162 and include both non-host signals and composite signals as received at the user end.

The operations of television signal processor 285A are now further described in relation to the functional block diagrams of Figures 6A-6C. Figures 6A-6C apply to any implementation of IE demodulator 120A, for example the implementation of Figure 3, as well as the implementation of Figure 2. In Figure 6A, a generalized form of the process as just described with respect to IE demodulator 120A of Figure 2 is shown. In Figure 6A, selector and splitter 650A selects those of user-end multiplexed signals 142X that are received composite signals 652A. That is, selector and splitter 650A selects the multiplexed signals that have been embedded with data intended for use by IE demodulator 120A. Information extractor 670A extracts data signals 124A from received composite signals 652A and provides them to data receiver 190A. Selector and splitter 650A also provides user-end multiplexed signals 142X to television signal processor 655A that performs functions such as those noted above with respect to television signal processor 285A. Processor 655A provides television signals 122A, corresponding with those of user-end multiplexed signals 142X that are composite signals and those that are not, to television receiver 180A. In some implementations, as represented by Figure 6B, all of television signals 122A may be extracted from composite signals and, optionally, further processed by television processor 675A, which performs functions as noted above with respect to processors 655A and 285A. As shown in Figure 6C, television signal processor 685A (corresponding to processors 675A, 655A, and 285A) may be external to IE demodulator 120A. Extracted data signals 124A-5 in this implementation are processed by processor 685A and then provided, as one or more of television signals 122A, to television receiver 180A. As noted, one or more of the functions of processor 685A may also be performed instead by television receiver 180A in alternative implementations.

<u>Data Rate Analyzer 295A</u>. Data rate analyzer 295A analyzes extracted data signals 124A in order to determine, or to provide information for data rate selector 225 to determine, a rate at which IE modulator 110 may embed data. (See method step 857.) Analyzer 295A transmits information to IE modulator 110 relating to the determined rate, as represented by transmitted data-rate data 297A. This transmission may be accomplished over a return channel of cable network 199 or in accordance with other known techniques, or future ones.

Any of a variety of conventional techniques may be employed so that analyzer 295A may analyze extracted data signals 124A. For example, information embedder 220

may embed a predetermined test signal in a host signal associated with IE demodulator 120A at an initial, or default, data rate. Analyzer 295A analyzes the test signal in accordance with any known error-detection and quantification technique to determine the error rate. If the error rate is lower than a nominal value based, for example, on the signal-to-noise ratio expected in view of the distance from the head end of cable network 199 to IE demodulator 120A, then analyzer 295A may indicate by transmitted data-rate data 297A that the data rate may be increased. If the error rate is higher than the nominal value, then analyzer 295A may indicate by transmitted data-rate data 297A that the data rate may be decreased so that, for example, error-detection and/or error correction information may be added to the embedded data. Similarly, after an initial data rate has been determined based on the test signal, analyzer 295A of the illustrated implementation continues to monitor error-detection information included with embedded data to determine when the rate of errors has increased.

Analyzer 295A may apply any of a variety of criteria to determine when the data rate should be adjusted. For example, analyzer 295A may calculate an average error rate over any one or more time periods and implement an adjustment when the average rate increases above a threshold value. As will be appreciated by those of ordinary skill in the relevant art, many conventional techniques may be employed both to detect changes in error rates and/or signal-to-noise ratios and also to determine the amount by which the data rate should be adjusted in response to those changes. Analyzer 295A may employ known data storage and computational devices and techniques to determine the error rate and adjusted data rate and provide the adjusted data rate information to data rate selector 225. Alternatively or in addition, and also in accordance with known devices and techniques, it may provide information regarding extracted data signals 124A and/or the error rate of those signals to data rate selector 225 so that data rate selector 225 may determine whether, and to what value, the data rate should be adjusted. That is, determinations of error rate and data rate may be made either by data rate analyzer analyzer 295A, data rate selector 225, or both in various implementations.

The System of Figure 3

Generally, the functional elements of the system of Figure 3 perform the same functions, in the same manner, as those functional elements of Figure 2 having like reference numbers except for the left-most numeral (which is "2" for elements of Figure 2 and "3" for elements of Figure 3). For example, host signals selector and optional de-

multiplexers 210 and 310 perform like functions in like manners; data rate analyzers 295A and 395A perform like functions in like manners, and so on. The system of Figure 3 differs from that of Figure 2, however, in that it is assumed for illustrative purposes that television signals 162 as provided in Figure 3 are in a broadcast band and in a broadcast format. Thus, the functions of transforming from a source format to a broadcast format (as illustratively performed by transformer 240 of Figure 2) and of transforming from a base band to a broadcast band (as illustratively performed by multiplexer and broadcast-band transformer 230 of Figure 2) need not be performed in the system of Figure 3.

Information embedder 320 may embed data into host signals 312 selected by selector 310 in the broadcast band. However, depending on the IE techniques being used and/or other factors, such as the availability of appropriate hardware and its costs, it may also be convenient that this embedding take place in a base band. Thus, information embedder 320 optionally includes a band converter and deconverter so that host signals in a broadcast band are selected and then converted to a base band, information is embedded in the base band, and the composite signal with embedded information is converted again to the broadcast band.

For purposes of illustration, it is now assumed that information embedder 320 has optionally converted the selected host signals to a base band, then embedded information to generate a composite signals in the base band, and then converted the composite signals to the broadcast band. Consequently, IE demodulator 120A typically includes broadcast-band to base-band transformer 370A so that information extractor 390A may extract information from received composite signals in the base band. That is, since information was embedded in the base band, it is typically convenient to extract it in the base band. However, it typically is not required that IE demodulator 120A of Figure 3 also include a broadcast-format to source-format transformer, such as element 280A of Figure 2. The reason is that it was illustratively assumed that information embedder 320 embedded information in a host signal that was in a broadcast format. Thus, information may typically be extracted from a composite signal in the broadcast format. In contrast, the information embedding of Figure 2 was illustratively assumed to take place on a host signal in a source format and thus transformer 280A was employed to transform the received composite signal to the source format for information extraction.

The System of Figure 7

Generally, the functional elements of the system of Figure 7 perform the same functions, in the same manner, as those functional elements of Figures 2 or 3 having like reference numbers except for the left-most numeral (which is "2" or "3" for elements of Figures 2 and 3, respectively, and "7" for elements of Figure 7). However, for purposes of clarity of illustration only, some optional elements shown in Figures 2 and 3 have been omitted from Figure 7. For example, elements corresponding to data rate selectors 225 and 325 and data rate analyzers 295A and 395A have been omitted from Figure 7. It will be understood that these optional elements may be included in the system of Figure 7 and perform functions similar to those shown in Figures 2 and/or 3.

The system of Figure 7 is referred to as being "backward compatible." This term means that the signals provided to user ends in accordance with this system may be processed by an IE demodulator employing IE techniques such as IE demodulator 120A of Figures 2 or 3, by a conventional cable demodulator that does not employ IE techniques, or by a demodulator such as backward-compatible demodulators 704 (represented by demodulators 704A and 704N) that are capable of employing conventional demodulation and/or demodulation in accordance with IE techniques.

In particular, backward-compatible modem system 700 includes a backward-compatible modulator 702 at a head end of cable network 199 and any number "N" of backward-compatible demodulators 704 at user ends of cable network 199. In some implementations, some or all of the user ends of cable network 199 may be coupled to backward-compatible demodulators 704, to IE demodulators 120 described with respect to Figures 2 or 3, and/or to conventional cable demodulators. Modulator 702 includes host signals selector 710 that selects and optionally de-multiplexes television signals 162 as described above with respect to the operations of selectors 210 and 310. Selector 710 provides selected host signals 712 to information embedder 720 for embedding and non-host signals 716 to multiplexer 730 for multiplexing.

Modulator 702 also includes information embedder 720 that employs IE techniques for embedding data signals 172 into host signals 712 to form composite signals 722, and performs further functions as described above with respect to information embedders 220 and/or 320. In particular, information embedder 720 may also include an optional band converter and/or band deconverter as described with respect to the operations of information embedder 320.

Another element of modulator 702 is multiplexer 730 that performs functions such as those described with respect to multiplexer and transformer 230 and/or multiplexer 330. In addition, multiplexer 730 multiplexes data signals 172 into a conventional data channel such as conventional data channel 166 of the cable plant of Figure 1C. (See decision element 827 and method step 830 of Figure 8.) In this manner, modulator 702 provides backward compatibility with respect to demodulators that operate on data carried in a conventional data channel. Moreover, because data signals 172 are also embedded into composite signals that also are multiplexed by multiplexer 730, the multiplexed signal may be utilized by demodulators employing IE techniques. That is, multiplexer 730 generates backward-compatible head-end multiplexed signals 732 that are transmitted by the head end of cable network 199 to various neighborhoods as described above with respect to the transmission of head-end multiplexed signals 112. For purposes of illustration, it is assumed that a cable "X" (not shown) carries backward-compatible head-end multiplexed signals 732X to a neighborhood "X" that includes a user end at which backward-compatible demodulator 704A is located, and that a cable "Y" (also not shown) carries backward-compatible head-end multiplexed signals 732Y to a neighborhood "Y" that includes a user end at which backward-compatible demodulator 704N is located.

Backward-compatible demodulator 704A receives backward-compatible user-end multiplexed signals 742X that correspond with backward-compatible head-end multiplexed signals 732X. Signals 742X are selected and split by composite signals selector and splitter 750A in a manner similar to that described above with respect to the operations of splitters 250A and 350A. Splitter 750A also provides signals 742X to conventional cable demodulator 755A that operates in accordance with known techniques to provide appropriate signals to television receiver 180A and to data receiver 190A. In particular, in one implementation, demodulator 755A demultiplexes the signals associated with conventional data channel 166 of signals 742X, thereby generating demultiplexed data signals 757A that are provided to data receiver 190A. (See method step 860.) Demodulator 755A provides other of signals 742X, such as those associated with analog television channels 172 and/or digital television channels 174, to television receiver 180A or, optionally, to TV signal processor 785A that performs functions similar to those described above with respect to TV signal processors 285A and/or 385A.

As will now be appreciated by those skilled in the relevant art, there are many other variations by which backward compatibility may be implemented by demodulator 704A. For example, splitter 750A may split, or demultiplex, the data signals associated with conventional data channel 166 from signals 742X and provide them to data receiver 190A rather than to demodulator 755A.

Splitter 750A selects and splits received composite signals 754A, corresponding to host signals 712, in a manner similar to that described above with respect to splitters 250A and 350A. Signals 754A may be transformed as described with respect to transformers 270A, 280A, or 370A, as appropriate with respect to bands and formats as noted above. Similar to the functions described with respect to extractors 290A and 390a, information extractor 760A operates on transformed composite signals 772A provided by transformer 770A in order to extract data corresponding to those of data signals 172 intended for backward-compatible demodulator 704A. Information extractor 760A provides the resulting extracted data signals 124A to data receiver 190A.

Further features of the above-described apparatuses and methods are described in the U.S. Patent Application entitled "SYSTEM AND METHOD FOR BACKWARD-COMPATIBLE MODULATION AND DEMODULATION OF DATA USING INFORMATION EMBEDDING IN TELEVISION SIGNALS," and in the U.S. Patent Application entitled "SYSTEM AND METHOD FOR VIRTUAL NODE DISTRIBUTION OF DATA EMBEDDED IN TELEVISION SIGNALS," both of which are referred to above and are hereby incorporated by reference herein.

Having now described various aspects of the present invention, it should be apparent to those skilled in the relevant art that the foregoing is illustrative only and not limiting, having been presented by way of example only. For instance, many other schemes for distributing functions among the various functional elements of the illustrated embodiment are possible in accordance with the present invention. The functions of any element may be carried out in various ways in alternative embodiments. For example, multiplexing and or transformation functions described as being performed by functional elements of IE modulator 110 may, in other implementations, be performed by CMTS 130 and/or by other functional elements not included in IE modulator 110. As another example, some or all of the functions of data rate selector 225 may be performed by data rate analyzer 295, and *vice versa*. For example, in alternative implementations, selected data rates may be provided by a return channel of

the cable network as contrasted with the illustrated implementation in which data rate data is provided that enables data rate selector 225 to make this selection. As yet another of many possible examples, the functions ascribed above to TV signal processors 285, 385, and/or 785 may be carried out in alternative implementations by TV receiver 180, by demodulator 755, and/or by splitters 250, 350, and/or 750. In addition, functions performed by elements of the illustrated systems may be performed by external elements in alternative implementations. For instance, conventional cable demodulator 755 may be external to backward-compatible demodulator 704 so that, for example, demodulator 755 is housed in a separate box or enclosure from demodulator 704.

The operations carried out by some functional elements of the illustrated embodiments may, in alternative implementations, be carried out in whole or in part by humans and/or machines. For example, host signal selectors 210, 310, and/or 710 may, as described above, associate host signals with user ends based on signal-to-noise ratio or other characteristics of the signals received by the user ends. Also, host signal selectors 210, 310, and/or 710 may associate host signals with user ends based on data-rate usage or other factors. In some implementations, a human and/or machine, not necessarily included in IE modulator 110, may make one or more of these and other selections attributed in the illustrated embodiments to selectors 210, 310, and/or 710. As another of many possible examples, the operations of data rate selectors 225 or 325 may be carried out in whole or in part by humans and/or machines and the selected data rates may then be communicated to elements of IE modulator 110 as described above with respect to the illustrated implementations of data rate selectors 225 or 325.

The method steps and decision elements shown in Figure 8 also are illustrative only. Steps and/or decision elements may be combined, separated, carried out in other orders or sequences, carried out in parallel, or otherwise rearranged in alternative embodiments. Also, additional steps and/or decision elements may be added in alternative embodiments. Numerous other embodiments, and modifications thereof, are contemplated as falling within the scope of the present invention as defined by appended claims and equivalents thereto.

What is claimed is:

CLAIMS

1. A variable-rate information-embedding modem system for providing a plurality of data signals to a plurality of user ends of a cable network, comprising:

(1) an information-embedding modulator, including

(a) a host signals selector constructed and arranged to select a first host signal from a plurality of television signals based, at least in part, on an association between the first host signal and a first user end, and

(b) an information embedder coupled to the host signals selector to receive from it the first host signal, constructed and arranged to embed a first data signal into the first host signal at a first data rate, thereby generating a first composite signal that comprises a watermarked version of the first host signal; and

(2) a data rate selector constructed and arranged to select the first data rate.

2. The system of claim 1, wherein:

the information-embedding modulator comprises the data rate selector.

3. The system of claim 1, further comprising:

(3) a first information-embedding demodulator, coupled to the first user end, comprising the data rate selector.

4. The system of claim 1, wherein:

the information-embedding modulator is coupled to a head end of the cable network; and

the data rate selector selects the first data rate based, at least in part, on a first signal-to-noise ratio over the cable network to the first user end.

5. The system of claim 4, wherein:

the data rate selector determines the first signal-to-noise ratio based, at least in part, on a first distance from the head end to the first user end.

6. The system of claim 5, wherein:

the first distance is based on a default value.

7. The system of claim 5, wherein:

the first distance is measured.

8. The system of claim 4, wherein:

the data rate selector determines the first signal-to-noise ratio based, at least in part, on a default value.

9. The system of claim 1, wherein:

the information-embedding modulator is coupled to a head end of the cable network; and

the data rate selector selects the first data rate based, at least in part, on a user-defined acceptable level of distortion.

10. The system of claim 1, wherein:

the information-embedding modulator is coupled to a head end of the cable network; and

the host signals selector selects the first host signal based, at least in part, on a first signal-to-noise ratio over the cable network to the first user end.

11. The system of claim 10, wherein:

the host signals selector selects a second host signal from the plurality of television signals based, at least in part, on the first signal-to-noise ratio and on a second signal-to-noise ratio over the cable network to a second user end;

the data rate selector selects a second data rate at which to embed a second data signal into the second host signal; and

the information embedder receives the second host signal from the host signal selector and embeds the second data signal into the second host signal at the second data rate, thereby generating a second composite signal that comprises a watermarked version of the second host signal.

12. The system of claim 1, wherein:

the host signals selector determines the association between the first host signal and the first user end based, at least in part, on one or more characteristics of the first host signal.

13. The system of claim 12, wherein:

the one or more characteristics include the video frequency composition of the first host signal.

14. The system of claim 12, wherein:

the one or more characteristics include the audio frequency composition of the first host signal.

15. The system of claim 1, wherein:

the data rate selector selects the first data rate based, at least in part, on one or more characteristics of the first host signal.

16. The system of claim 15, wherein:

the one or more characteristics include the video frequency composition of the first host signal.

17. The system of claim 15, wherein:

the one or more characteristics include the audio frequency composition of the first host signal.

18. The system of claim 1, further comprising:

(3) a first information-embedding demodulator coupled to the first user end for receiving a set of user-end multiplexed signals including the first composite signal, including

(a) a first composite signals selector and splitter constructed and arranged to select from the set of user-end multiplexed signals a first received composite signal corresponding to the first host signal,

(b) a first information extractor, constructed and arranged to extract from the first received composite signal a first extracted data signal corresponding to the first data signal, and

(c) a first data rate analyzer constructed and arranged to determine a first error rate of the first extracted data signal.

19. The system of claim 18, wherein:

the first data rate analyzer determines the first error rate based, at least in part, on a test signal included in the first data signal.

20. The system of claim 18, wherein:

the first data rate analyzer determines the first error rate based, at least in part, on an error detection technique.

21. The system of claim 18, wherein:

the data rate selector selects the first data rate based, at least in part, on the first error rate.

22. The system of claim 18, wherein:

the first data rate analyzer further is constructed and arranged to determine a second error rate of the first extracted data signal at a time subsequent to determining the first error rate; and

the data rate selector selects the first data rate based, at least in part, on applying one or more statistical measures to the first and second error rates.

23. The system of claim 22, wherein:

the data rate selector selects the first data rate based, at least in part, on an average error rate.

24. A method for providing a plurality of data signals to a plurality of user ends of a cable network using variable-rate information-embedding, comprising the steps of:

(1) selecting a first host signal from a plurality of television signals based, at least in part, on an association between the first host signal and a first user end;

(2) selecting a first data rate; and

(3) embedding a first data signal into the first host signal at the first data rate, thereby generating a first composite signal that comprises a watermarked version of the first host signal.

25. The method of claim 24, further comprising the step of:

(4) determining a first signal-to-noise ratio over the cable network to the first user end; and

wherein step (2) is based, at least in part, on the first signal-to-noise ratio.

26. The method of claim 25, wherein:

step (4) is based, at least in part, on a first distance from a head end of the cable network to the first user end.

27. The method of claim 26, wherein:

the first distance is a default value.

28. The method of claim 26, wherein:

step (4) includes the step of measuring the first distance.

29. The method of claim 24, wherein:

step (2) is based, at least in part, on a user-defined acceptable level of distortion.

30. The method of claim 24, further comprising the step of:

(4) determining a first signal-to-noise ratio over the cable network to the first user end; and

wherein step (1) is based, at least in part, on the first signal-to-noise ratio.

31. The method of claim 30, further comprising the steps of:

(5) determining a second signal-to-noise ratio over the cable network to a second user end;

(6) selecting a second host signal from the plurality of television signals based, at least in part, on the first signal-to-noise ratio and on the second signal-to-noise ratio;

(7) selecting a second data rate at which to embed a second data signal into the second host signal; and

(8) embedding the second data signal into the second host signal at the second data rate, thereby generating a second composite signal that comprises a watermarked version of the second host signal.

32. The method of claim 24, further comprising the step of:

(4) determining the association between the first host signal and the first user end based, at least in part, on one or more characteristics of the first host signal.

33. The method of claim 32, wherein:

the one or more characteristics include the video frequency composition of the first host signal.

34. The method of claim 32, wherein:

the one or more characteristics include the audio frequency composition of the first host signal.

35. The method of claim 24, wherein:

step (2) is based, at least in part, on one or more characteristics of the first host signal.

36. The method of claim 35, wherein:

the one or more characteristics include the video frequency composition of the first host signal.

37. The method of claim 35, wherein:

the one or more characteristics include the audio frequency composition of the first host signal.

38. The method of claim 24, further comprising:

(4) receiving at the first user end a set of user-end multiplexed signals including the first composite signal;

(5) selecting from the set of user-end multiplexed signals a first received composite signal corresponding to the first host signal;

(6) extracting from the first received composite signal a first extracted data signal corresponding to the first data signal, and

(7) determining a first error rate of the first extracted data signal.

39. The method of claim 38, wherein:

step (7) is based, at least in part, on a test signal included in the first data signal.

40. The method of claim 38, wherein:

step (7) is based, at least in part, on an error detection technique.

41. The method of claim 38, wherein:

step (2) is based, at least in part, on the first error rate.

42. The method of claim 38, further comprising the steps of:

(8) determining a second error rate of the first extracted data signal at a time subsequent to determining the first error rate; and

wherein step (2) is based, at least in part, on applying one or more statistical measures to the first and second error rates.

43. The method of claim 42, wherein:

step (2) is based, at least in part, on an average error rate.

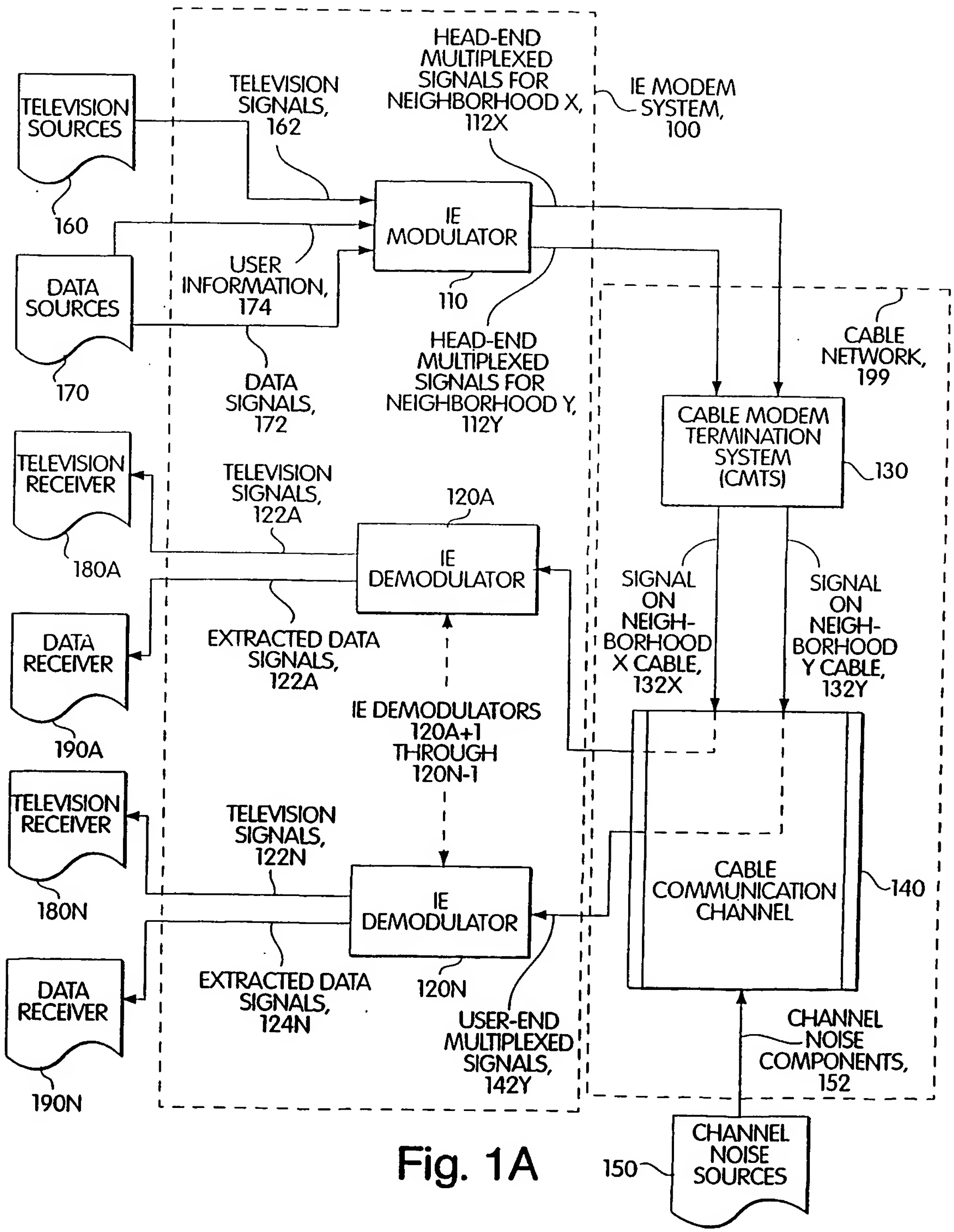

TELEVISION SOURCES
160
TELEVISION SIGNALS, 162
HEAD-END MULTIPLEXED SIGNALS FOR NEIGHBORHOOD X, 112X
IE MODEM SYSTEM, 100
IE MODULATOR
110
DATA SOURCES
170
USER INFORMATION, 174
DATA SIGNALS, 172
HEAD-END MULTIPLEXED SIGNALS FOR NEIGHBORHOOD Y, 112Y
CABLE NETWORK, 199
CABLE MODEM TERMINATION SYSTEM (CMTS)
130
TELEVISION RECEIVER
180A
TELEVISION SIGNALS, 122A
120A
IE DEMODULATOR
SIGNAL ON NEIGH-BORHOOD X CABLE, 132X
SIGNAL ON NEIGH-BORHOOD Y CABLE, 132Y
DATA RECEIVER
190A
EXTRACTED DATA SIGNALS, 122A
IE DEMODULATORS 120A+1 THROUGH 120N-1
TELEVISION RECEIVER
180N
TELEVISION SIGNALS, 122N
IE DEMODULATOR
CABLE COMMUNICATION CHANNEL
140
DATA RECEIVER
190N
EXTRACTED DATA SIGNALS, 124N
120N
USER-END MULTIPLEXED SIGNALS, 142Y
CHANNEL NOISE COMPONENTS, 152
150
CHANNEL NOISE SOURCES

Fig. 1A

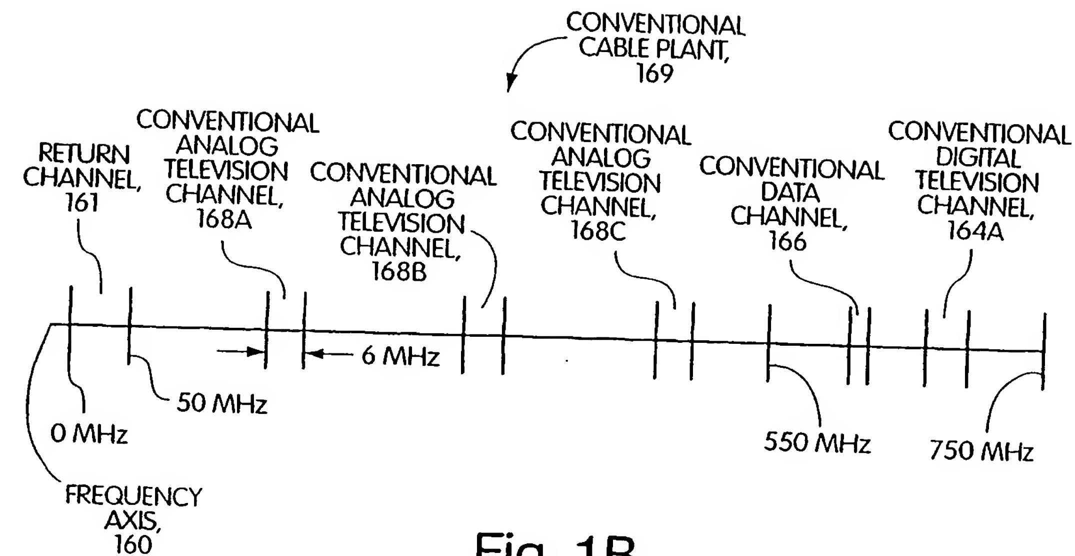

CONVENTIONAL CABLE PLANT, 169
RETURN CHANNEL, 161
CONVENTIONAL ANALOG TELEVISION CHANNEL, 168A
CONVENTIONAL ANALOG TELEVISION CHANNEL, 168B
CONVENTIONAL ANALOG TELEVISION CHANNEL, 168C
CONVENTIONAL DATA CHANNEL, 166
CONVENTIONAL DIGITAL TELEVISION CHANNEL, 164A
6 MHz
50 MHz
0 MHz
550 MHz
750 MHz
FREQUENCY AXIS, 160

Fig. 1B

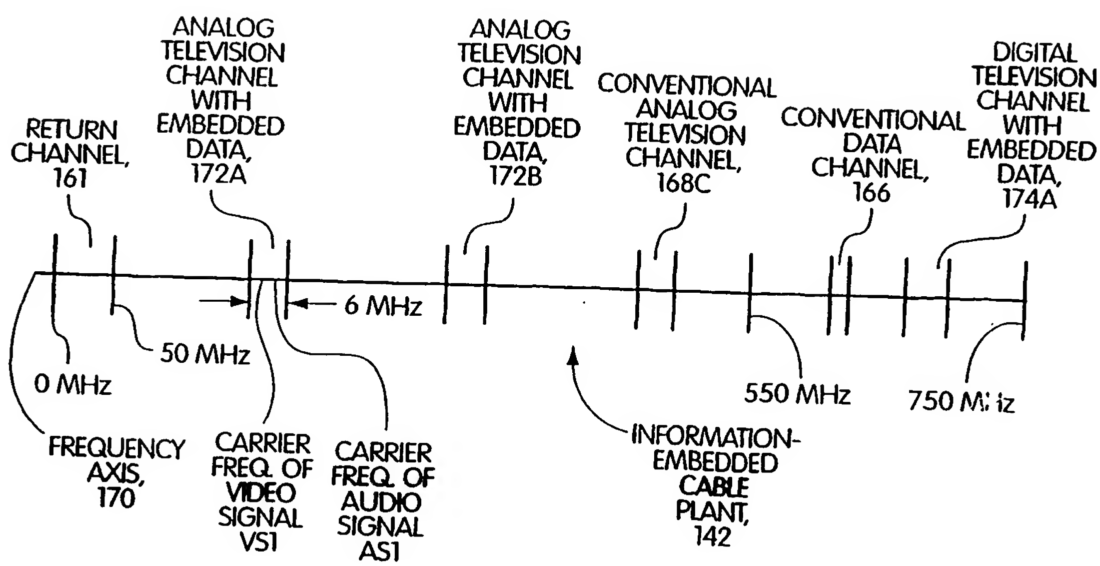
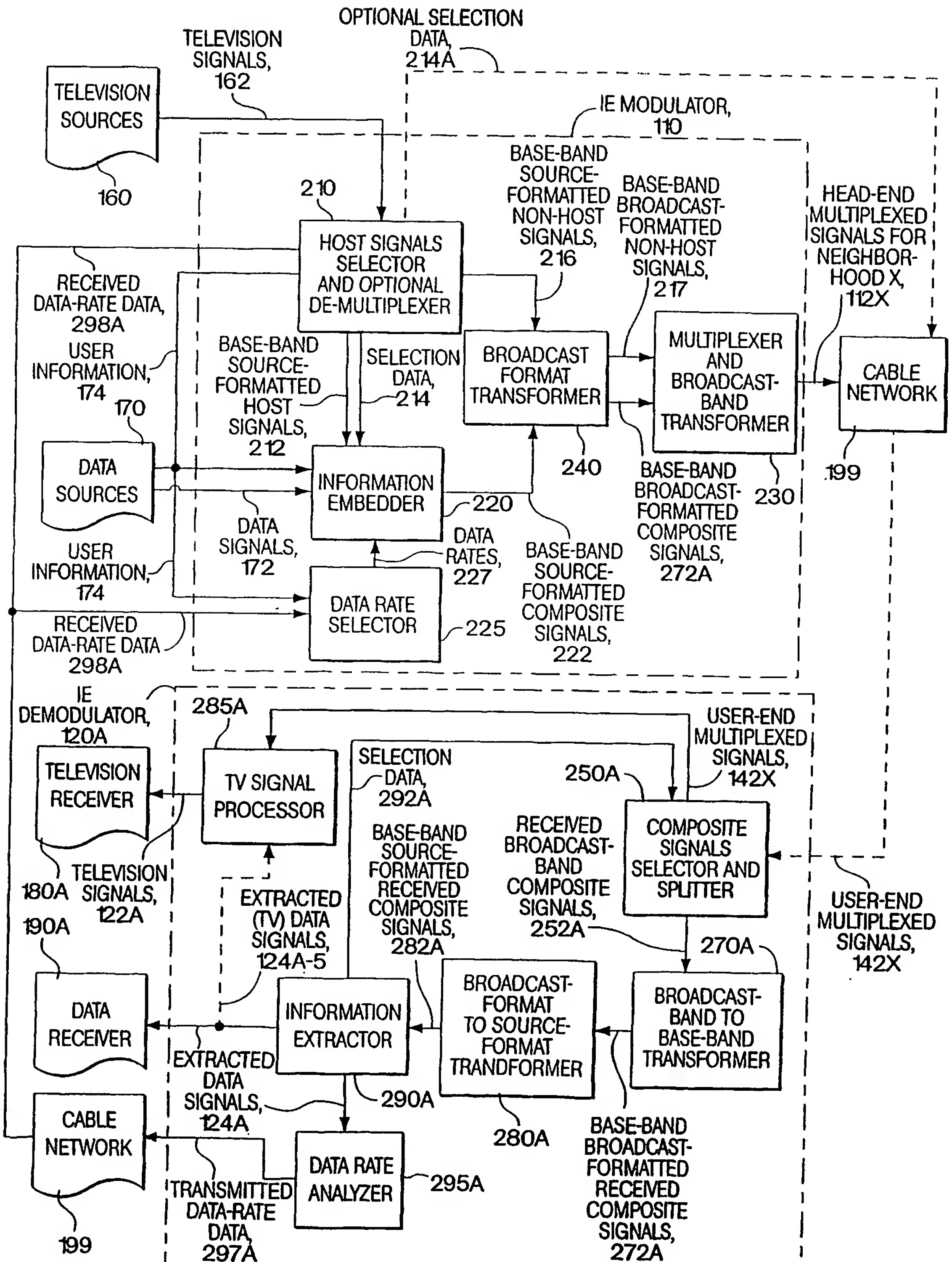
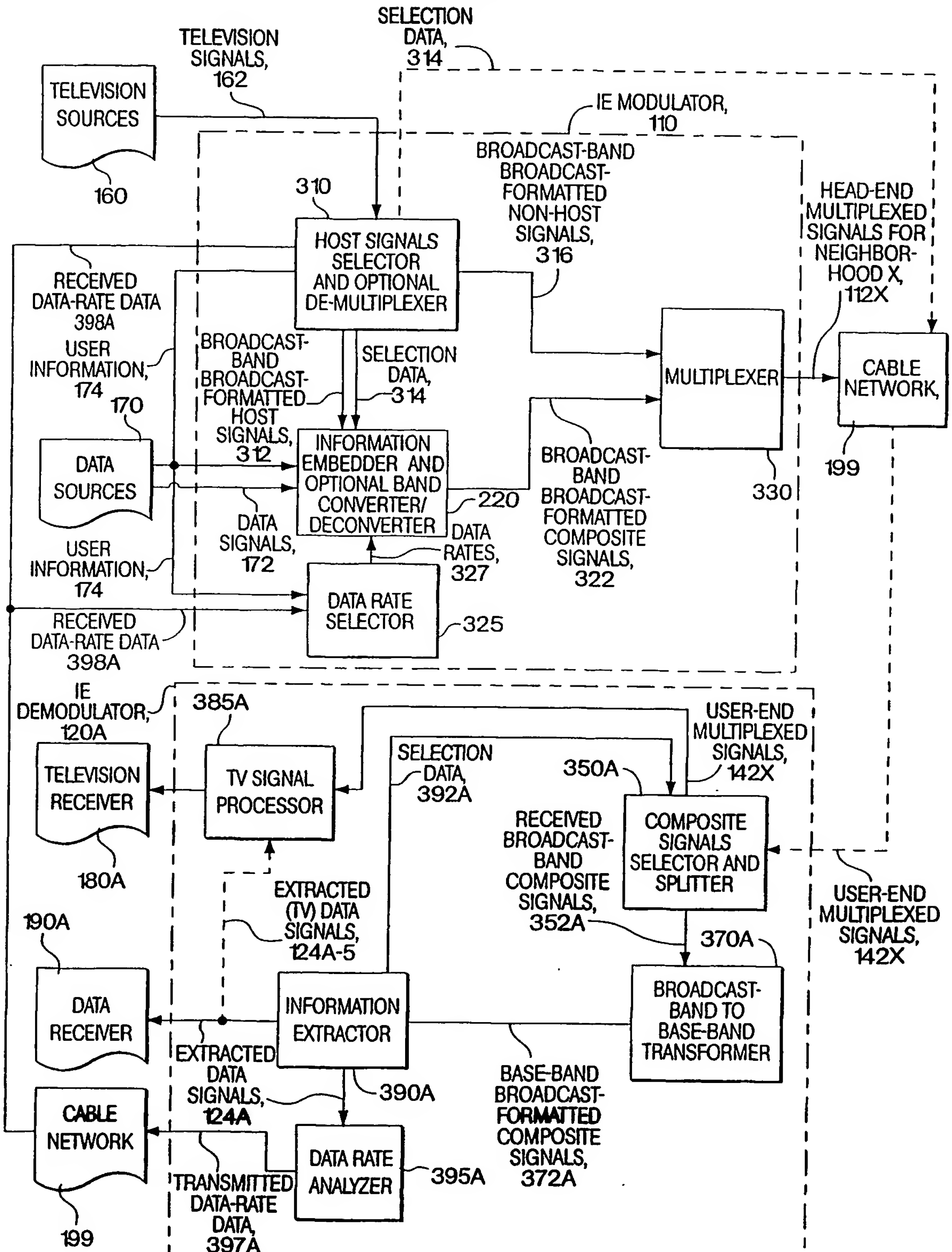

RETURN CHANNEL, 161
ANALOG TELEVISION CHANNEL WITH EMBEDDED DATA, 172A
ANALOG TELEVISION CHANNEL WITH EMBEDDED DATA, 172B
CONVENTIONAL ANALOG TELEVISION CHANNEL, 168C
CONVENTIONAL DATA CHANNEL, 166
DIGITAL TELEVISION CHANNEL WITH EMBEDDED DATA, 174A
6 MHz
50 MHz
0 MHz
550 MHz
FREQUENCY AXIS, 170
CARRIER FREQ. OF VIDEO SIGNAL VS1
CARRIER FREQ. OF AUDIO SIGNAL AS1
INFORMATION-EMBEDDED CABLE PLANT, 142

Fig. 1C



OPTIONAL SELECTION DATA, 214A
TELEVISION SIGNALS, 162
TELEVISION SOURCES
160
IE MODULATOR, 110
210
HOST SIGNALS SELECTOR AND OPTIONAL DE-MULTIPLEXER
BASE-BAND SOURCE-FORMATTED NON-HOST SIGNALS, 216
BASE-BAND BROADCAST-FORMATTED NON-HOST SIGNALS, 217
HEAD-END MULTIPLEXED SIGNALS FOR NEIGHBOR-HOOD X, 112X
RECEIVED DATA-RATE DATA, 298A
USER INFORMATION, 174
BASE-BAND SOURCE-FORMATTED HOST SIGNALS, 212
SELECTION DATA, 214
BROADCAST FORMAT TRANSFORMER
MULTIPLEXER AND BROADCAST-BAND TRANSFORMER
CABLE NETWORK
170
DATA SOURCES
INFORMATION EMBEDDER
240
BASE-BAND BROADCAST-FORMATTED COMPOSITE SIGNALS, 272A
230
199
220
DATA SIGNALS, 172
DATA RATES, 227
BASE-BAND SOURCE-FORMATTED COMPOSITE SIGNALS, 222
USER INFORMATION, 174
DATA RATE SELECTOR
225
RECEIVED DATA-RATE DATA 298A
IE DEMODULATOR, 120A
285A
USER-END MULTIPLEXED SIGNALS, 142X
TELEVISION RECEIVER
TV SIGNAL PROCESSOR
SELECTION DATA, 292A
250A
COMPOSITE SIGNALS SELECTOR AND SPLITTER
BASE-BAND SOURCE-FORMATTED RECEIVED COMPOSITE SIGNALS, 282A
RECEIVED BROADCAST-BAND COMPOSITE SIGNALS, 252A
180A
TELEVISION SIGNALS, 122A
USER-END MULTIPLEXED SIGNALS, 142X
190A
EXTRACTED (TV) DATA SIGNALS, 124A-5
270A
DATA RECEIVER
INFORMATION EXTRACTOR
BROADCAST-FORMAT TO SOURCE-FORMAT TRANDFORMER
BROADCAST-BAND TO BASE-BAND TRANSFORMER
EXTRACTED DATA SIGNALS, 124A
290A
CABLE NETWORK
280A
DATA RATE ANALYZER
295A
BASE-BAND BROADCAST-FORMATTED RECEIVED COMPOSITE SIGNALS, 272A
TRANSMITTED DATA-RATE DATA, 297A
199

Fig. 2



SELECTION DATA, 314
TELEVISION SIGNALS, 162
TELEVISION SOURCES
160
IE MODULATOR, 110
BROADCAST-BAND BROADCAST-FORMATTED NON-HOST SIGNALS, 316
310
HOST SIGNALS SELECTOR AND OPTIONAL DE-MULTIPLEXER
HEAD-END MULTIPLEXED SIGNALS FOR NEIGHBOR-HOOD X, 112X
RECEIVED DATA-RATE DATA 398A
USER INFORMATION, 174
BROADCAST-BAND BROADCAST-FORMATTED HOST SIGNALS, 312
SELECTION DATA, 314
MULTIPLEXER
CABLE NETWORK,
170
DATA SOURCES
INFORMATION EMBEDDER AND OPTIONAL BAND CONVERTER/ DECONVERTER
220
BROADCAST-BAND BROADCAST-FORMATTED COMPOSITE SIGNALS, 322
330
199
DATA SIGNALS, 172
DATA RATES, 327
USER INFORMATION, 174
DATA RATE SELECTOR
325
RECEIVED DATA-RATE DATA 398A
IE DEMODULATOR, 120A
385A
USER-END MULTIPLEXED SIGNALS, 142X
TELEVISION RECEIVER
TV SIGNAL PROCESSOR
SELECTION DATA, 392A
350A
COMPOSITE SIGNALS SELECTOR AND SPLITTER
RECEIVED BROADCAST-BAND COMPOSITE SIGNALS, 352A
180A
EXTRACTED (TV) DATA SIGNALS, 124A-5
USER-END MULTIPLEXED SIGNALS, 142X
370A
190A
BROADCAST-BAND TO BASE-BAND TRANSFORMER
DATA RECEIVER
INFORMATION EXTRACTOR
EXTRACTED DATA SIGNALS, 124A
390A
BASE-BAND BROADCAST-FORMATTED COMPOSITE SIGNALS, 372A
CABLE NETWORK
DATA RATE ANALYZER
395A
TRANSMITTED DATA-RATE DATA, 397A
199

Fig. 3

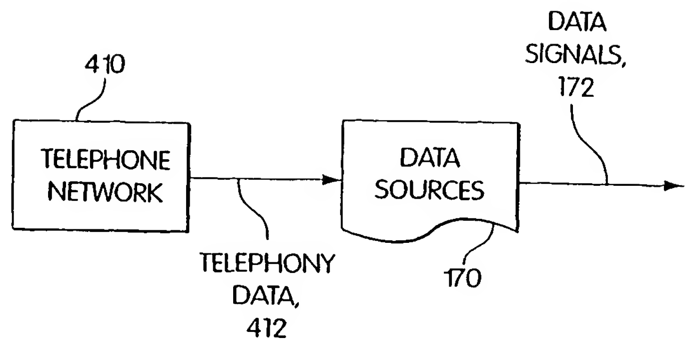


Fig. 4A

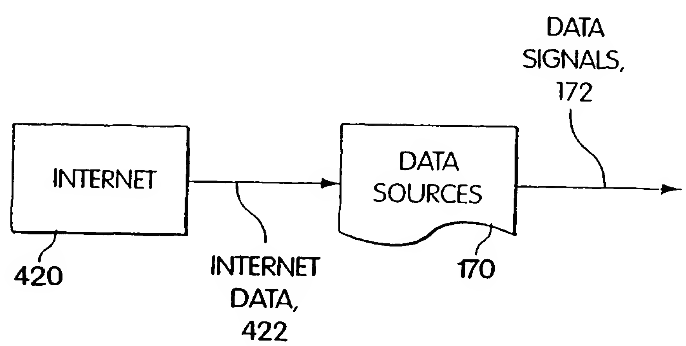


Fig. 4B

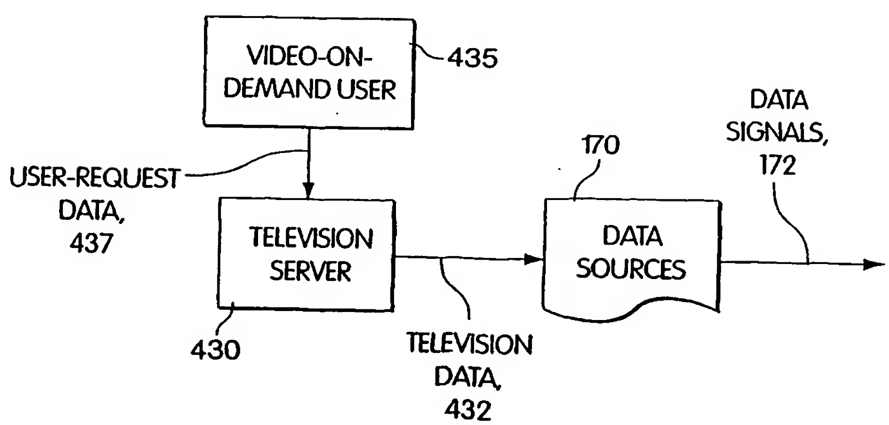


Fig. 4C

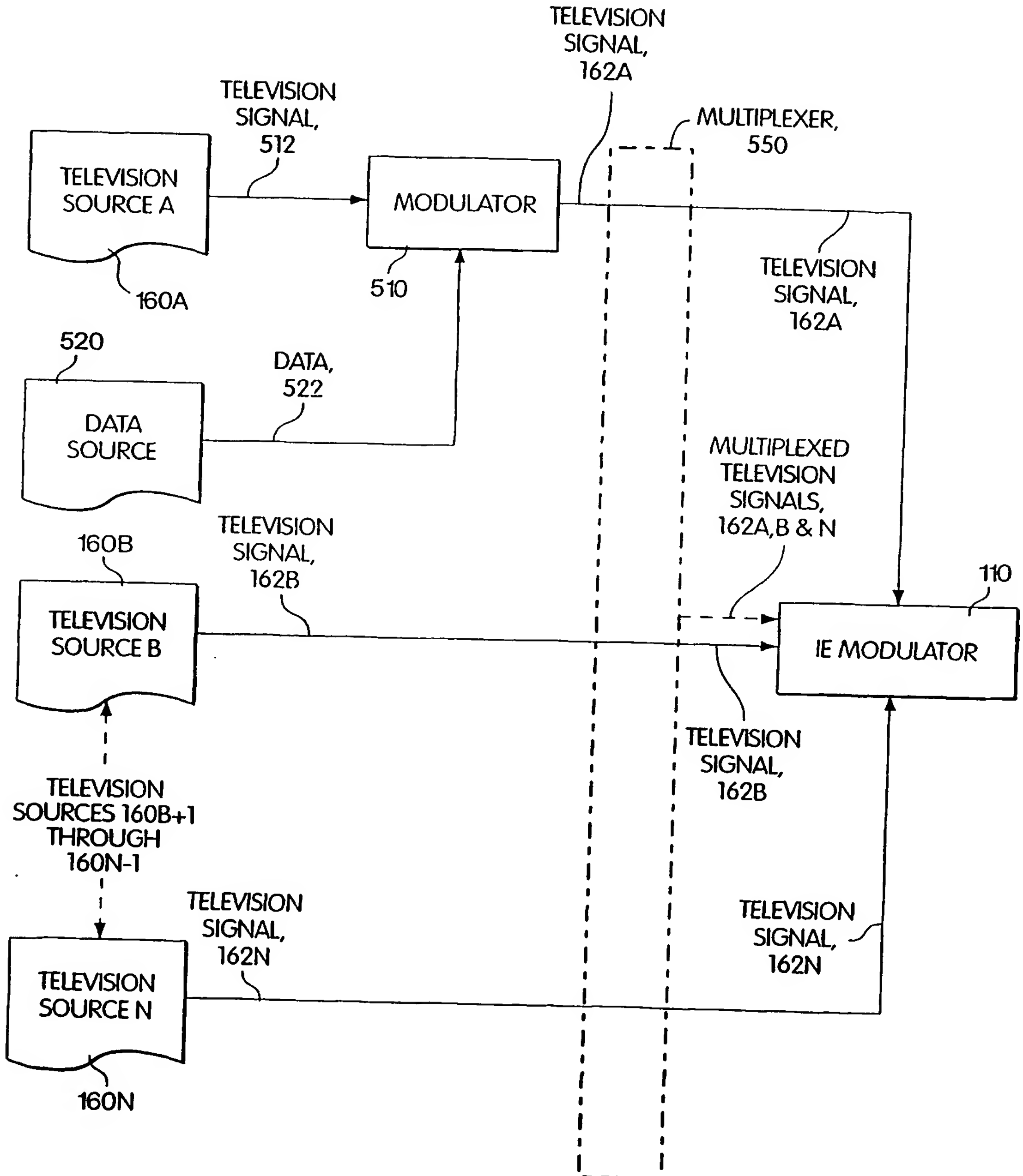
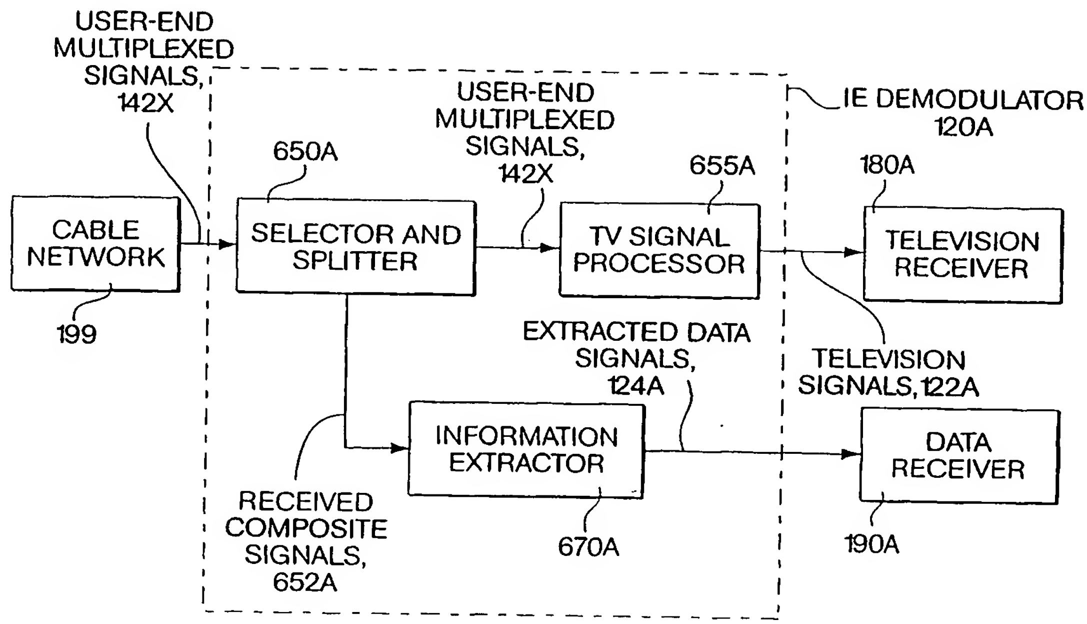
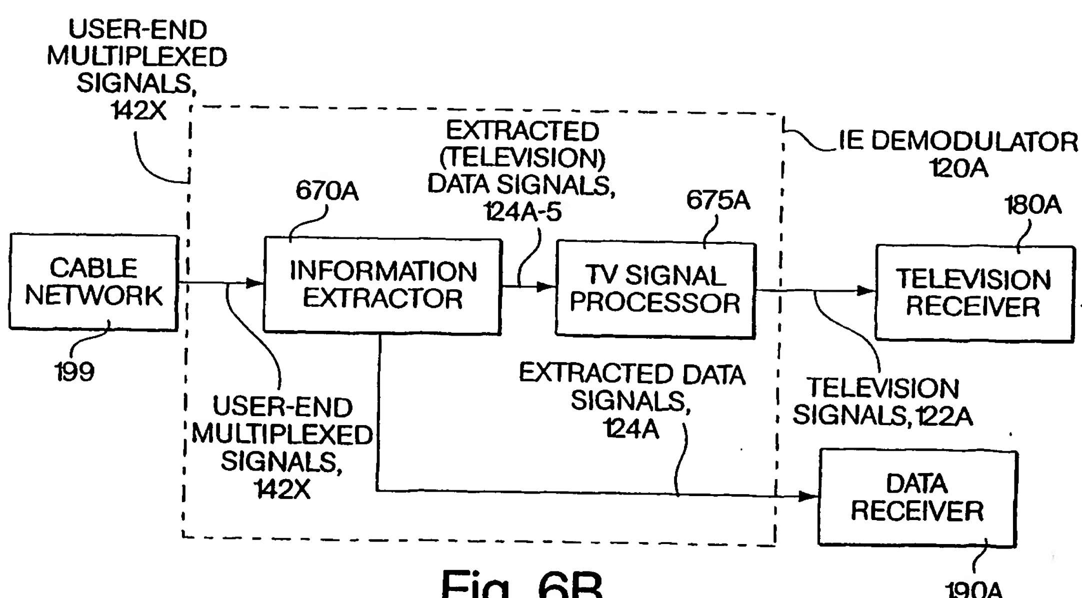

TELEVISION SOURCE A
160A
TELEVISION SIGNAL, 512
MODULATOR
510
TELEVISION SIGNAL, 162A
MULTIPLEXER, 550
TELEVISION SIGNAL, 162A
520
DATA SOURCE
DATA, 522
MULTIPLEXED TELEVISION SIGNALS, 162A,B & N
160B
TELEVISION SOURCE B
TELEVISION SIGNAL, 162B
110
IE MODULATOR
TELEVISION SIGNAL, 162B
TELEVISION SOURCES 160B+1 THROUGH 160N-1
TELEVISION SOURCE N
160N
TELEVISION SIGNAL, 162N
TELEVISION SIGNAL, 162N

Fig. 5



USER-END MULTIPLEXED SIGNALS, 142X
IE DEMODULATOR 120A
USER-END MULTIPLEXED SIGNALS, 142X
650A
655A
180A
CABLE NETWORK
SELECTOR AND SPLITTER
TV SIGNAL PROCESSOR
TELEVISION RECEIVER
199
EXTRACTED DATA SIGNALS, 124A
TELEVISION SIGNALS, 122A
INFORMATION EXTRACTOR
DATA RECEIVER
RECEIVED COMPOSITE SIGNALS, 652A
670A
190A

Fig. 6A



USER-END MULTIPLEXED SIGNALS, 142X
IE DEMODULATOR 120A
EXTRACTED (TELEVISION) DATA SIGNALS, 124A-5
670A
675A
180A
CABLE NETWORK
INFORMATION EXTRACTOR
TV SIGNAL PROCESSOR
TELEVISION RECEIVER
199
EXTRACTED DATA SIGNALS, 124A
TELEVISION SIGNALS, 122A
USER-END MULTIPLEXED SIGNALS, 142X
DATA RECEIVER
190A

Fig. 6B

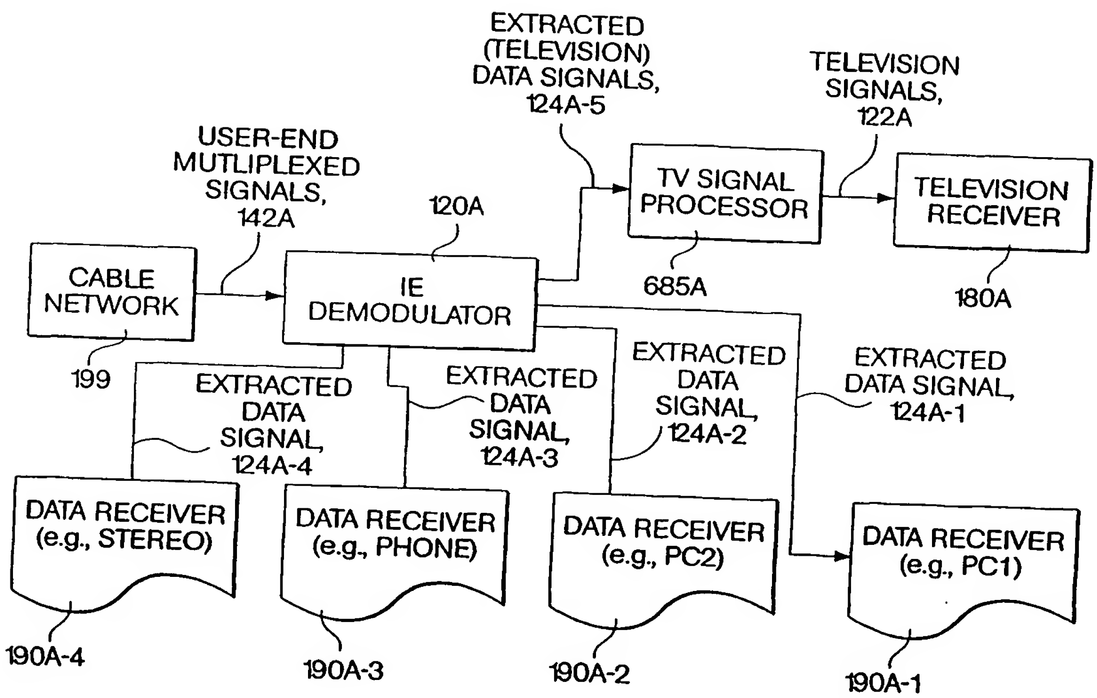

EXTRACTED
(TELEVISION)
DATA SIGNALS,
124A-5
TELEVISION
SIGNALS,
122A
USER-END
MUTLIPLEXED
SIGNALS,
142A
120A
TV SIGNAL
PROCESSOR
TELEVISION
RECEIVER
CABLE
NETWORK
IE
DEMODULATOR
685A
180A
199
EXTRACTED
DATA
SIGNAL,
124A-4
EXTRACTED
DATA
SIGNAL,
124A-3
EXTRACTED
DATA
SIGNAL,
124A-2
EXTRACTED
DATA SIGNAL,
124A-1
DATA RECEIVER
(e.g., STEREO)
DATA RECEIVER
(e.g., PHONE)
DATA RECEIVER
(e.g., PC2)
DATA RECEIVER
(e.g., PC1)
190A-4
190A-3
190A-2
190A-1

Fig. 6C

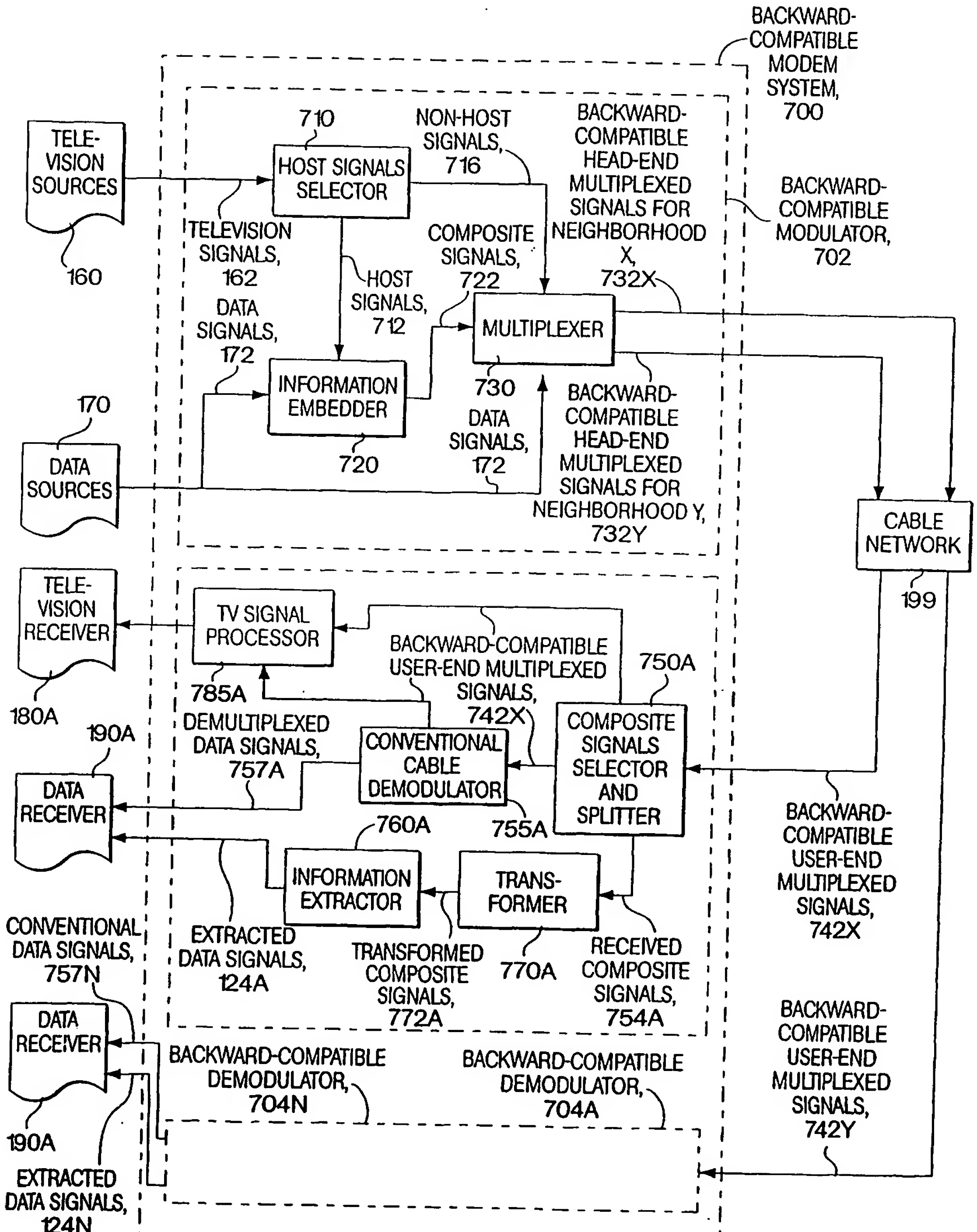

BACKWARD-COMPATIBLE MODEM SYSTEM, 700
TELE-VISION SOURCES
160
710
HOST SIGNALS SELECTOR
NON-HOST SIGNALS, 716
BACKWARD-COMPATIBLE HEAD-END MULTIPLEXED SIGNALS FOR NEIGHBORHOOD X, 732X
BACKWARD-COMPATIBLE MODULATOR, 702
TELEVISION SIGNALS, 162
HOST SIGNALS, 712
COMPOSITE SIGNALS, 722
DATA SIGNALS, 172
MULTIPLEXER
730
INFORMATION EMBEDDER
720
170
DATA SOURCES
DATA SIGNALS, 172
BACKWARD-COMPATIBLE HEAD-END MULTIPLEXED SIGNALS FOR NEIGHBORHOOD Y, 732Y
CABLE NETWORK
199
TELE-VISION RECEIVER
180A
TV SIGNAL PROCESSOR
785A
BACKWARD-COMPATIBLE USER-END MULTIPLEXED SIGNALS, 742X
750A
DEMULTIPLEXED DATA SIGNALS, 757A
CONVENTIONAL CABLE DEMODULATOR
755A
COMPOSITE SIGNALS SELECTOR AND SPLITTER
190A
DATA RECEIVER
760A
INFORMATION EXTRACTOR
TRANS-FORMER
BACKWARD-COMPATIBLE USER-END MULTIPLEXED SIGNALS, 742X
CONVENTIONAL DATA SIGNALS, 757N
EXTRACTED DATA SIGNALS, 124A
TRANSFORMED COMPOSITE SIGNALS, 772A
770A
RECEIVED COMPOSITE SIGNALS, 754A
DATA RECEIVER
BACKWARD-COMPATIBLE DEMODULATOR, 704N
BACKWARD-COMPATIBLE DEMODULATOR, 704A
BACKWARD-COMPATIBLE USER-END MULTIPLEXED SIGNALS, 742Y
190A
EXTRACTED DATA SIGNALS, 124N

Fig. 7

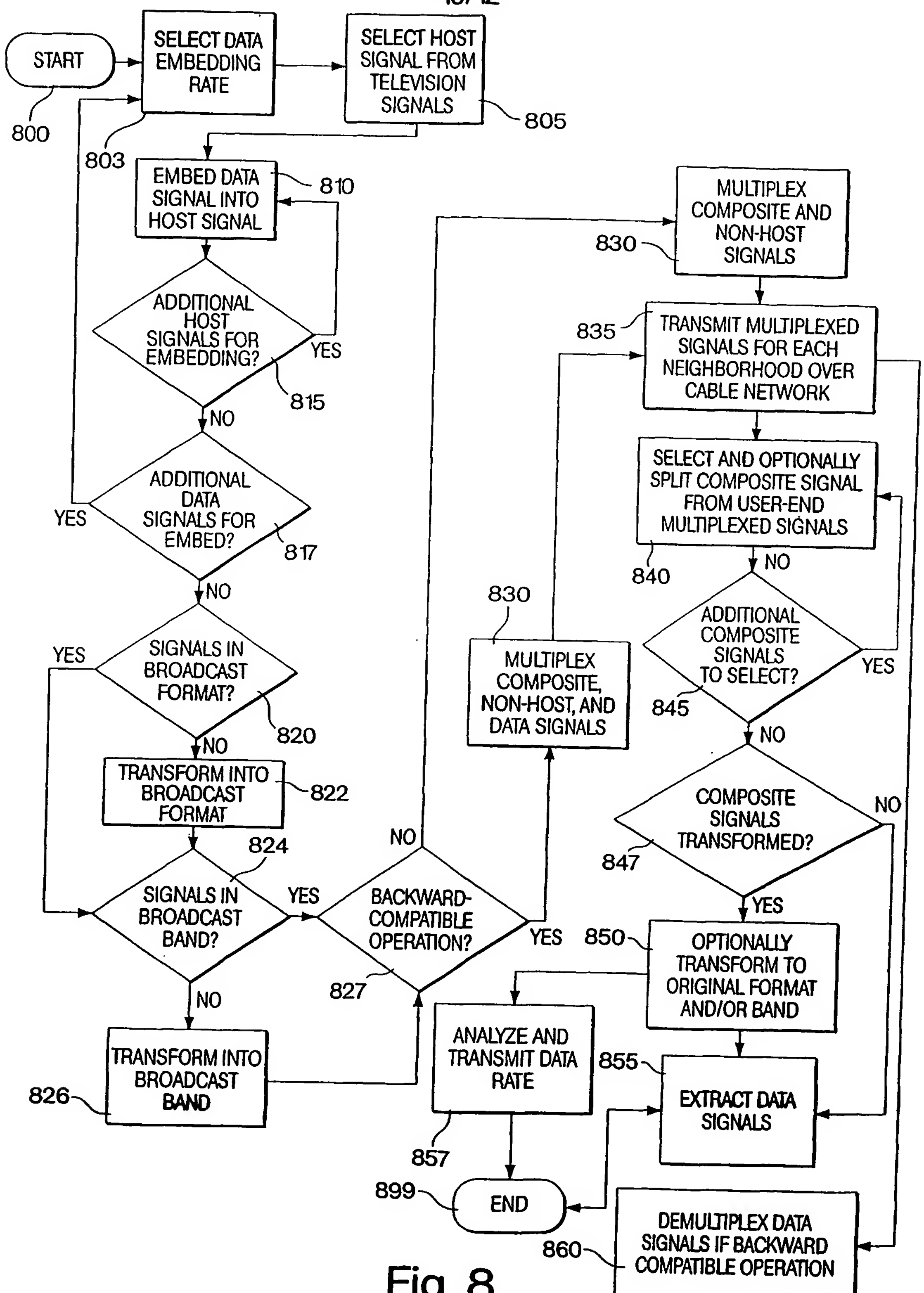

START
800
SELECT DATA EMBEDDING RATE
803
SELECT HOST SIGNAL FROM TELEVISION SIGNALS
805
EMBED DATA SIGNAL INTO HOST SIGNAL
810
ADDITIONAL HOST SIGNALS FOR EMBEDDING?
815
YES
NO
ADDITIONAL DATA SIGNALS FOR EMBED?
817
YES
NO
SIGNALS IN BROADCAST FORMAT?
820
YES
NO
TRANSFORM INTO BROADCAST FORMAT
822
SIGNALS IN BROADCAST BAND?
824
YES
NO
TRANSFORM INTO BROADCAST BAND
826
BACKWARD-COMPATIBLE OPERATION?
827
NO
YES
MULTIPLEX COMPOSITE AND NON-HOST SIGNALS
830
MULTIPLEX COMPOSITE, NON-HOST, AND DATA SIGNALS
830
TRANSMIT MULTIPLEXED SIGNALS FOR EACH NEIGHBORHOOD OVER CABLE NETWORK
835
SELECT AND OPTIONALLY SPLIT COMPOSITE SIGNAL FROM USER-END MULTIPLEXED SIGNALS
840
ADDITIONAL COMPOSITE SIGNALS TO SELECT?
845
YES
NO
COMPOSITE SIGNALS TRANSFORMED?
847
NO
YES
OPTIONALLY TRANSFORM TO ORIGINAL FORMAT AND/OR BAND
850
ANALYZE AND TRANSMIT DATA RATE
857
EXTRACT DATA SIGNALS
855
DEMULTIPLEX DATA SIGNALS IF BACKWARD COMPATIBLE OPERATION
860
END
899

Fig. 8

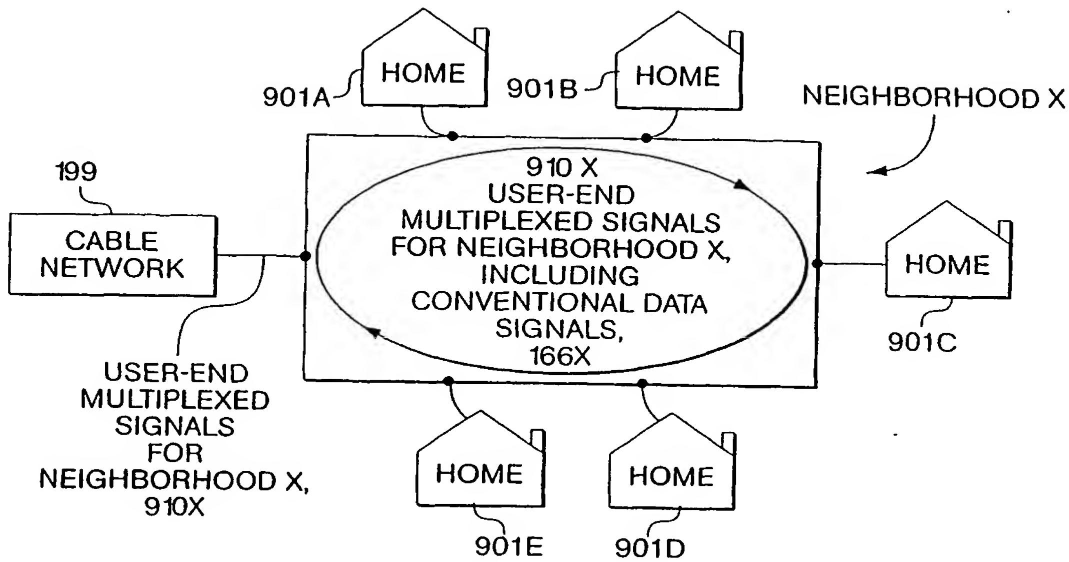


Fig. 9A
(PRIOR ART)

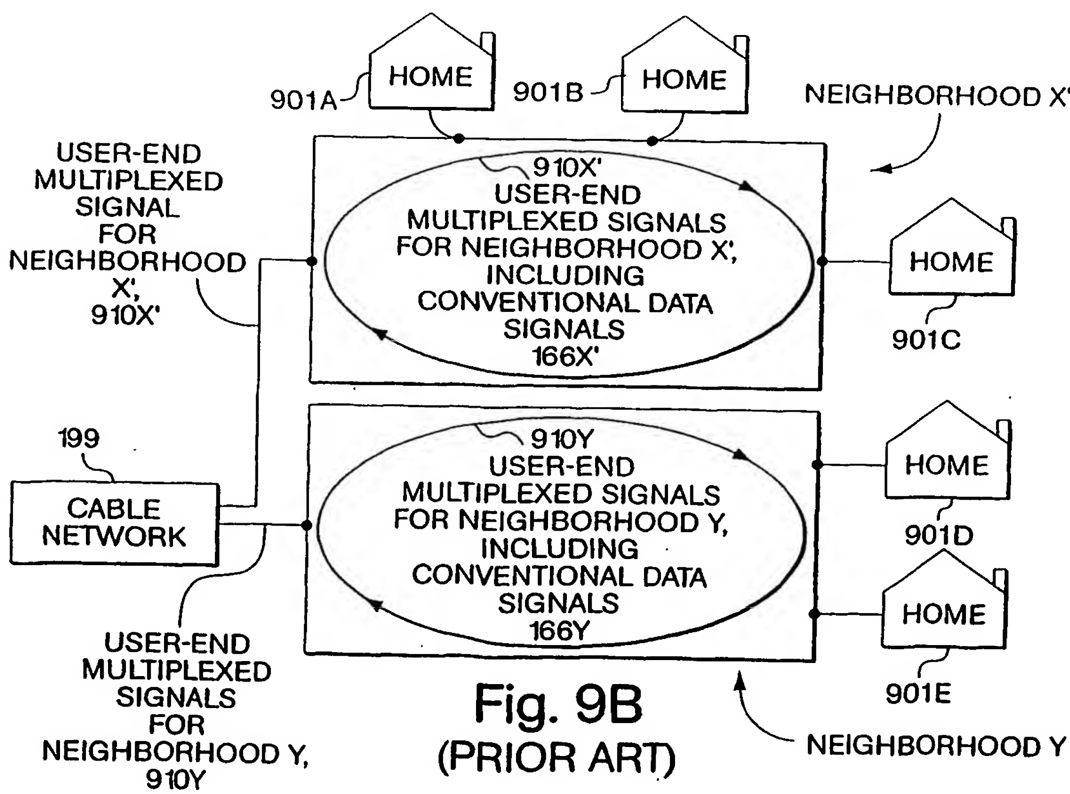


Fig. 9B
(PRIOR ART)

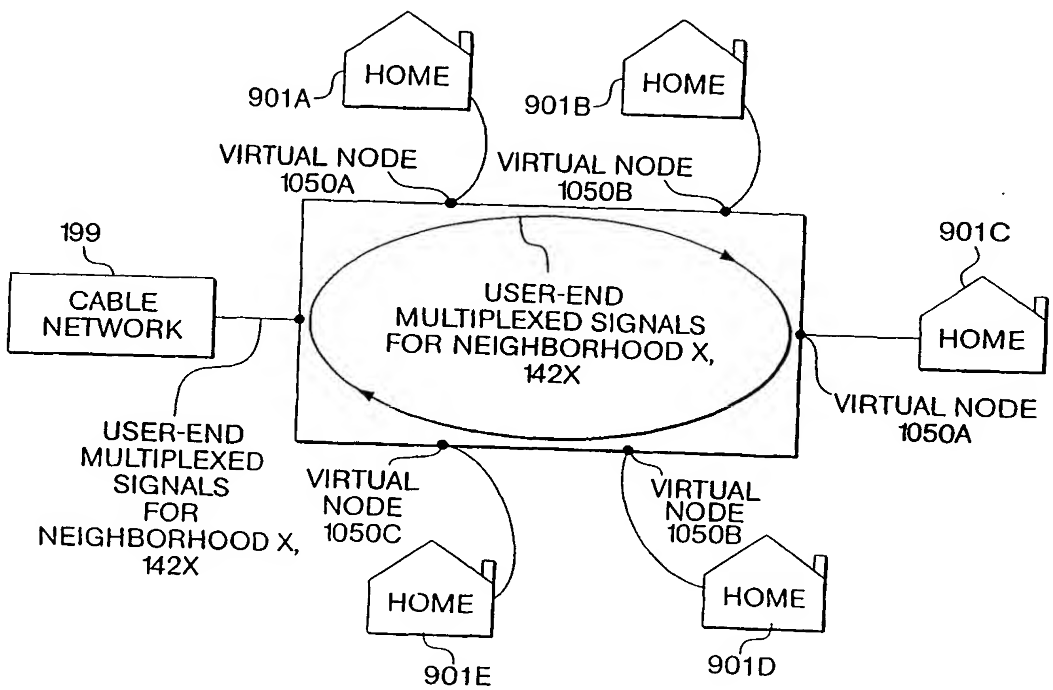


Fig. 10A

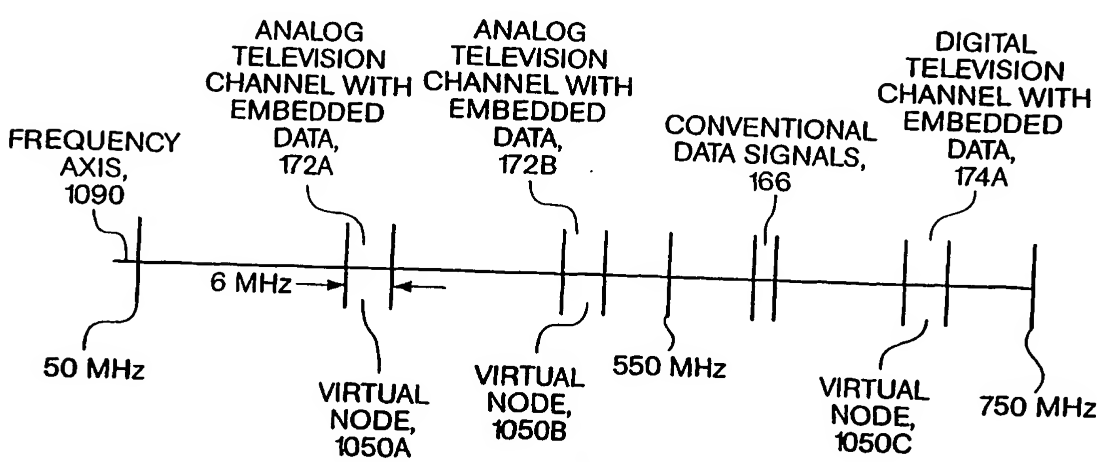


Fig. 10B

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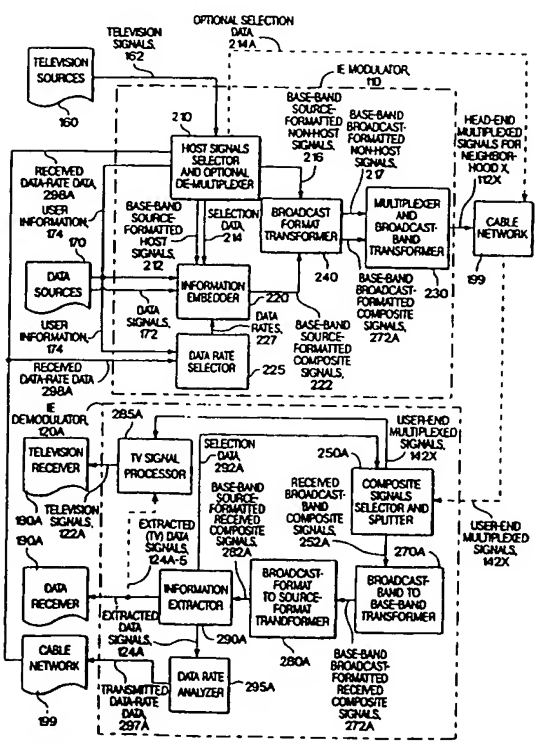
[Continued on next page]

(54) Title: SYSTEM FOR VARIABLE-RATE MODULATION AND DEMODULATION OF DATA USING INFORMATION EMBEDDING IN TELEVISION SIGNALS



(57) Abstract: A system is described for providing data signals to user ends of a cable network (199) using variable-rate information-embedding. The system includes a DR selector (225) that selects (210), a host signal from two or more TV signals based on an association between the host signal and the user. A first data signal is embedded (220) into the host signal at a first data rate (DR), thereby generating a composite signal that comprises a digitally watermarked version of the host signal. The DR selectors may be included in modulators (110). Additionally DR selectors may be included in demodulators at the users ends. The DR selectors may select a DR for embedding data to be transmitted to a particular user based on the S/N ratio over the network. Determination of this ratio may be partially based on the distance from the user to the headend. Also the DR may be based on a user-defined acceptable level of distortion.

WO 02/07425 A3

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

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13 June 2002

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/19036

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H04N 7/08, 14; H04L 9/00
US CL : 725/95, 111; 348/403; 380/51
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 725/95, 111; 348/403; 380/51

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST:
variable rate, digital watermark, modulation, rate selection, S/N

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,044,396 A (ADAMS) 28 MARCH 2000; Abstract; col. 3, lines 54-67 thru col. 4, lines 1-55.	1-43
Y	US 6,037,984 A (ISNARDI, et al) 14 MARCH 2000. Abstract; col. 1, lines 54-60; col. 4, lines 31-35.	1-43
Y	US 5,889,868 A (MOSKOWITZ, et al) 30 MARCH 1999. Abstract; col. 2, lines 25-45; col. 6, lines 46-55; col. 10, lines 15-35; col. 11, lines 30-55.	1-43

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Date of the actual completion of the international search 19 JANUARY 2002	Date of mailing of the international search report 05 FEB 2002
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